Blue Green Algae Work Group of the State Water Resources Control Board and Office of Environmental Health and Hazard Assessment

Cyanobacteria in California Recreational Water Bodies

Providing Voluntary Guidance about Harmful Algal Blooms, Their Monitoring, and Public Notification

DRAFT

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Purpose

The purpose of this document is to provide guidance to local, state, and tribal regulators to protect people, pets, and livestock from the effects of toxic cyanobacteria in non-marine water bodies. This draft will be updated as new information and data become available. Pets and livestock are included in this guidance because they have been harmed or killed by exposure to cyanobacterial blooms and are important to their owners.

Specifically, the guidance will provide:

1. background information on cyanotoxins and their health effects,
2. information on the status of environmental sampling for cyanobacteria and their toxins,
3. information to educate the recreating public,
4. guidance for notification and posting by the local health officer, and
5. resources and websites for more detailed information.

This guidance does not address cyanobacteria in drinking water supplies. Public drinking water systems, which are regulated by the California Department of Health Services (DHS), have algae control programs to avoid taste and odor problems associated with surface water supplies. These programs help minimize the appearance of cyanobacterial blooms. Nevertheless, cyanobacteria will receive more attention from drinking water suppliers, since cyanobacteria, as well as other freshwater algae, and their toxins are included in US EPA's Candidate Contaminant List, and in the methods development phase (List 3) of US EPA's unregulated contaminants requiring monitoring. Information on cyanobacterial blooms and drinking water is available at the DHS website: **http://www.dhs.ca.gov/bga**.The DHS website is updated with pertinent new information regarding cyanobacteria in both drinking water and recreational waters, and has links to its drinking water and environmental management programs.

Background

Cyanobacteria, also known as blue-green algae, are common and naturally occurring in many aquatic systems around the world. When they occur, they generally reflect the overall status of the specific water body, in terms of conditions that can contribute to blooms, including decreased water flow and decreased water mixing, elevated temperature, the presence of excess nutrients, or other conditions. Certain species of cyanobacteria have the ability to produce toxins.

At least 46 species of cyanobacteria have been shown to be toxic to vertebrates (Chorus & Bartram, 1999). Some of the more common genera in California include *Microcystis*, *Anabaena*, *Aphanizomenon*, *Lyngbya, Planktothrix*, *Nostoc* and *Cylindrospermopsis*. All of these genera occur in other parts of the world.

Cyanobacterial blooms have been detected in non-marine water bodies in California, including Los Vaqueros and Mallard Reservoirs, the Sacramento River, the San Joaquin River, the Old River, Crowley Lake, Black Butte Lake, Clear Lake, the South Fork Eel River, Lake Hensley, Lake Isabella, Big Bear Lake, Perris Lake, Lake Elsinore, Canyon Lake, Pinto Lake, Lake Hennessey, Lake Britton, the Klamath River and its reservoirs, and in surface water components of the Metropolitan Water District of Southern California. Cyanobacterial blooms also occur in Big Lagoon, an estuary, and in the Salton Sea, an inland salt-water lake. To date the specific cyanotoxins identified in California include microcystins and anatoxin-a. While cyanobacteria can produce other toxins, the focus of this guidance will be on microcystin and anatoxin-a, the state's most commonly detected cyanotoxins. There may be other toxins that will be added to this document when identified.

Various factors control the quantity of toxins produced by cyanobacteria. If cyanotoxins are produced, they are found within the cell during most of a bloom

event. Toxins are released into the water when the cells die and their cellular membranes disintegrate, a process called lysis. The released toxin will dilute and eventually degrade over time. The level of toxins, and risk of exposure to dissolved toxins, may increase immediately following the peak of a bloom. Cyanotoxins have been detected in the water phase as a result of extra-cellular release, even though the producer cells (i.e., cell density) are absent or found in low numbers (Lawton *et al.*, 1994). The potential for human exposure during this period may also increase as water clarity improves and appears more suitable for recreational activities.

Recreational, cultural and subsistence exposure to water bodies containing cyanobacteria and their toxins can cause:

- rashes (pruritic and non-pruritic),
- eye, nose, mouth or throat irritation (including oral blistering),
- allergic reactions (including urticarial rash),
- headache,
- gastrointestinal upset (abdominal pain, nausea, vomiting, diarrhea),
- malaise, and
- other effects. Reports of fever, dyspnea, and pneumonia have also been associated with recreational exposure to these organisms. One death in the United States was attributed to swimming in a cyanobacteria contaminated pond. High levels of cyanotoxins in drinking water have caused serious illness resulting in hospitalization in some parts of the world.

Pets are also at risk. Since 2001 it is suspected that the deaths of nine dogs resulted from their exposure to microcystins or anatoxin-a from swimming in water bodies with cyanobacterial blooms in Humboldt and Mendocino Counties. Most mammalian poisonings reported in the scientific literature have been due to livestock drinking microcystin-contaminated water. For example, cattle in Oklahoma, Colorado and Georgia exposed to *Microcystis aeruginosa* experienced generalized weakness, hyperthermia, anorexia, diarrhea, pale mucous membranes, mental derangement, muscle tremors, coma and death within a few days (Frazier *et al.*, 1998, Puschner *et al.*, 1998, Short & Edwards, 1990). Acute liver necrosis was the most common pathological lesion. British military recruits in the United Kingdom exposed to a bloom of *M. aeruginosa* during an exercise in a reservoir experienced abdominal pain, vomiting, diarrhea, sore throat, blistering of the mouth, and pneumonia (Turner *et al.*, 1990).

<u>Microcystins</u>

Microcystins are the most commonly detected cyanotoxin across the globe (Chorus & Bartram, 1999). Cyanobacteria that are known to produce microcystins include *Microcystis, Planktothrix, Oscillatoria, Nostoc, Anabaena, Anabaenopsis and Hapalosiphon.* Microcystins are cyclic heptapeptides with over 70 known structural variants that have significant influence on the toxicity

and physio-chemical properties of the toxin. The most studied and common variant is microcystin-LR.

The mechanism of toxicity of microcystins is the inhibition of protein phosphatases. The inhibition of protein phosphatases can cause programmed cell death that can in turn lead to internal hemorrhaging of the liver. Exposure to microcystins has the potential to cause acute and chronic injury, depending on the dose and duration of exposure. Sub-acute damage to the liver is likely to go unnoticed up to levels that are near severe acute damage (Chorus *et al.*, 2000). Two aspects of chronic damage include progressive injury to the liver and tumor-promoting capacity. The International Agency for Research on Cancer found there was inadequate evidence for carcinogenicity of microcystin LR or *Microcystis* extracts (WHO, 2006). However like several other liver toxins, microcystins have been shown to promote liver tumors (Falconer & Buckley, 1989). Promoters increase the number of tumors when given after a chemical known to interact with DNA, but not when given alone.

The World Health Organization (WHO) has established a Tolerable Daily Intake (TDI) as well as Guideline Values (GVs) for microcystin toxin in water. These are useful in evaluating potential risk of adverse health impacts from exposure via drinking water as well as recreational water activities.

According to WHO, a TDI is the amount of a potentially harmful substance that can be consumed daily, via ingestion, over a lifetime, with negligible risk of adverse health effects. TDIs are based on scientific data and controlled laboratory studies of observed adverse health impacts. The TDI for microcystin-LR was based on observed acute effects on the liver. The primary study used to develop the microcystin-LR TDI is a 13-week oral ingestion mouse study. Because of lack of data, no long term chronic effects or carcinogenicity potential was used in the development of this TDI. Although TDIs do not account for multiple routes of exposure or cumulative risk due to exposure to multiple toxins, they are highly valuable in assessing the potential risk of adverse health effects from a single toxin. The WHO TDI for microcystin-LR toxin is 0.04 µg/kg body weight.

The GVs have been developed by the WHO to specifically address the probability of adverse effects occurring in individuals exposed to contaminated water during specific water use scenarios. GVs have been developed for drinking water consumption as well as recreational water exposure.

WHO guideline values represent a scientific consensus, based on broad international participation, of the health risk to humans associated with exposure to microbes and chemicals found in water. For recreational water exposure GVs are defined at three primary concentration levels: *mild or low*, *moderate* and *high probability* of risk for adverse health impacts if exposed at a given toxin concentration. GVs are calculated values. They are derived using the TDI for a

given chemical along with a person's average body weight and the estimated amount of contaminated water that may be ingested on a daily basis during a given activity. GVs do not take into account health risks that may be attributed to other routes of exposure, such as aerosol inhalation or skin contact. The WHO GV for moderate risk of adverse health effects from recreational exposure to microcystin in water is 20 μg/liter (or a density of approximately 100,000 cyanobacteria cells per milliliter (ml) of water). The WHO GV for high risk is the presence of active algal scums, which can increase cell densities 1000 to 1,000,000 fold.

Anatoxin-a

Anatoxin-a is an alkaloid neurotoxin that is produced by some strains of *Anabaena*, *Aphanizomenon* and *Oscillatoria* (Chorus & Bartram, 1999), and *Phormidium* (Gugger *et al.*, 2005) and *Cylindrospermum* (Chorus & Bartram, 1999). Anatoxin-a mimics the neurotransmitter acetylcholine, binds to nicotinic acetylcholine receptors and cannot be degraded by the enzyme acetylcholinesterase. The molecular activity of anatoxin-a leads to over stimulation of muscle cells and possibly paralysis followed by asphyxiation (Carmichael, 1997). In addition to anatoxin-a, anatoxin-a(s) and homoanatoxin have been identified from cyanobacteria and vary in their toxicity and mode of action.

The acutely toxic properties of anatoxin-a are obvious, since it affects the nervous system. Available data indicate that it is unlikely to cause chronic toxicity from limited exposure (Fawell *et al.*, 1994). At this time, the database is insufficient for a derivation of a TDI as human exposure information and suitable animal tests are lacking.

Exposures Pathways

The primary exposure pathway of concern for exposure to cyanotoxins is through ingestion of water. Dermal irritant or allergic effects are possible from skin contact with lipopolysaccharides found on algal cell surfaces; however the cyanotoxins are not likely to cross the skin barrier and enter the bloodstream. Inhalation and aspiration of toxin is possible, especially through activities where the toxin is aerosolized, such as water skiing or splashing.

Ingestion of water can occur through both incidental and intentional ingestion pathways. Incidental ingestion is more likely in recreational waters, especially in turbid or discolored lakes. The risk of incidental ingestion is particularly high for children playing in near-shore areas where scums tend to accumulate. Exposure levels can be broadly defined as high, moderate and low based on recreational activity (Table 1).

Table 1. Level of recreational activity (modified from (Queensland Health, 2001)).

Level of Exposure	Recreational Activity
High	Swimming, diving, water skiing
Moderate	Canoeing, sailing, rowing
Low to none	Fishing, pleasure cruising, picnicking, hiking

Ingestion of untreated water is never a good idea, as it increases risk of exposure to microorganisms such as bacteria, viruses, *Giardia*, and *Cryptosporidium*, as well as cyanobacteria. A possible scenario for the intentional ingestion of recreational water is the use of lake water for drinking or cooking purposes by campers, hikers and backpackers. It is possible that some campers, hikers or backpackers have the mistaken belief that boiling, filtering or treating contaminated water with field equipment will make it potable. This scenario should be addressed in informational and advisory signs.

At this time, there is insufficient information to determine the risk of consuming fish caught in waters with toxigenic cyanobacteria. Studies have shown that toxins mainly accumulate in the liver and viscera of fish, although microcystins have been detected in the fillet (Magalhaes *et al.*, 2001, Vasconcelos, 1999, Xie *et al.*, 2005). At a minimum, the fish should be rinsed with potable water and the organs should be removed and discarded prior to cooking fillets. In one study, the muscle, as well as liver, of carnivorous fish contained higher microcystin concentrations than similar tissues from herbivorous fish (Xie et al., 2005). In addition, shellfish have been shown to accumulate cyanotoxins in edible tissue (Vasconcelos, 1999).

Monitoring

General Information

Assessing the human health risk posed by toxic cyanobacteria, or the potential for development of cyanobacterial blooms, and linking this to effective measures to protect public health within available resources, is complex. Currently there is no single analytical method that quantifies cyanobacterial toxicity and identifies the profile of microcystin variants within a water sample.

As an initial step in determining the prevalence of potentially harmful algal blooms in California the State Water Board, working with the Blue Green Algae Work Group, will standardize information collection on visible blue-green algae blooms. This information might include:

Historical records and local knowledge – historical records, if available, and information from the local community can be used to identify presence of

water bodies prone to cyanobacterial blooms. Members of the local community can often provide examples of human health incidents, pet or livestock mortalities and fish-kills associated with blooms and scums. A lack of historical and local evidence of blooms cannot be taken as assurance that cyanobacterial blooms have not occurred, or will not occur.

Physical data – planktonic cyanobacteria favor certain growing conditions that include surface water temperature above about 18 °C, and persistent thermal stratification with little mixing.

Hydraulic mixing and transport processes - the ratio between the depth of the mixed layer and the depth to which sufficient light for photosynthesis penetrates, along with data on flushing rates in lakes as well as river flow rates are useful because planktonic cyanobacteria do not usually attain high population densities in highly flushed environments with retention times (i.e. the time it takes for the water volume to be exchanged once) of less than 5-10 days, or in the open channels of flowing rivers. Cyanotoxins are water-soluble compounds that can readily move downstream; as such it may be prudent to monitor potential cyanotoxin concentrations downstream from a lake or reservoir where a bloom is occurring or has recently dispersed.

Chemical data - the mass development of cyanobacteria leading to blooms is dependent on the nutrient concentrations (especially phosphorus and nitrogen) in a water body. The relationship between mean chlorophyll *a* concentrations (as a simple measure of cyanobacterial and planktonic algal biomass) and annual mean phosphorus concentrations provides a valuable (but easily misused) basis for assessing the likelihood of planktonic biomass development.

Biological data - monitoring records are useful in contributing to the assessment of the likelihood, onset and persistence of cyanobacterial mass developments.

Monitoring Recreational Water Bodies

Simple visual observation of a water body is an important tool in recognizing blue-green algae. Materials that enable the identification of algal types (e.g., a field guide) provide an early-warning mechanism to help address concerns about blue-green algal blooms.

Characterizing the recreational water body (for example, by a sanitary survey) is also helpful in identifying situations and activities that might affect the overall water quality, not only for blue-green algae, but also for microbiological indicators (e.g., total and fecal coliforms, enterococcus, and E. coli) that may be important to consider for healthful recreation.

If a blue-green algal bloom occurs, water sample collection for algal species identification, algal cell enumeration or toxin analysis may be warranted. See Appendix 1 for additional discussion on this issue.

Reporting

Large blooms of blue-green algae, and any known occurrences of toxic cyanobacteria and their toxins (if toxin analysis has been performed) should be reported to local health and environmental health officials. Known occurrences of toxic cyanobacteria should also be reported to the State and Regional Water Boards. To the extent that historical information is available, it should be reported to the State Water Board. The State Water Board will provide a clearinghouse of reported algal blooms and toxic cyanobacteria, on a dedicated webpage that will be updated periodically.

The occurrence of large cyanobacterial blooms should also be reported to the county agricultural commissioner if grazing lands are proximal to the affected water body, and to the local offices of the State Department of Fish and Game, as well as U.S. Fish and Wildlife, to address concerns about effects on livestock and wildlife. If the blooms are observed on federal or tribal lands these should also be reported to the appropriate land managing authority (e.g., US Forest Service, Tribal Health Department, etc.)

Posting Warning Notices and Issuing Advisories

Local health agencies may post advisories regarding blue-green algal blooms or order closure of recreational waters. Recommended steps in determining whether to post a health advisory may include:

Hazard Identification

- Are there visual indications of a blue-green algal bloom (distinct green or blue-green discoloration or streaks along surface water, or an accumulation of scum in bays or along shorelines)?

- If water analysis for algae has been done, are toxigenic cyanobacterial species present? If Yes:

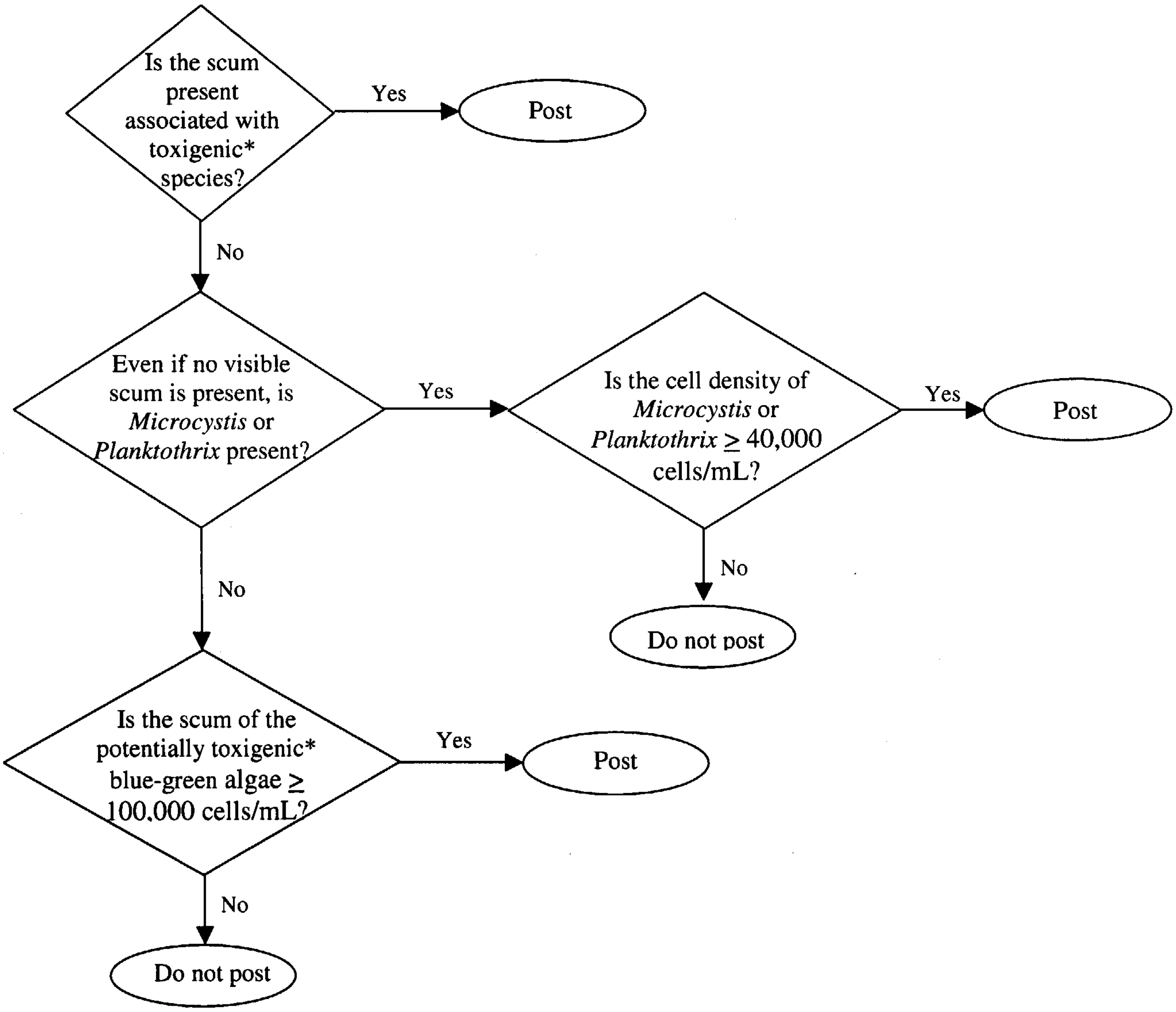
    - What species of toxigenic cyanobacteria are present?

    - What is the density of toxigenic species in the water?

Posting Decisions:

- If visible scum is present: Post warning signs and distribute informational brochures.

- When sampling with microbial identification is available, the following decision chart is recommended:



*Potentially toxic blue-green algae that have been detected in California include those of the genera *Anabaena, Microcystis, Aphanizomenon, and Gloeotrichia.* Additional blue-green algae that are known to be potentially toxic may be added to this list.

At this time, health impairments from exposure to cyanobacteria in recreational waters cannot be precisely defined or predicted. Recreational exposure to cyanotoxins via direct skin contact, inhalation, or inadvertent ingestion of water can cause rashes, allergies, and gastrointestinal problems for people working or recreating on the water (WHO, 2003). The long-term effects of such exposures or the effects of inhalation of toxins are not well known (Lopez *et al.*, 2007). However, the World Health Organization has developed a series of categories that compare cyanobacterial cell concentrations with the probability of adverse health effects:

Guidelines for Algae and Cyanobacteria in Fresh Water
(from WHO Guidelines for Safe Recreational Water Environments, Table 8.3, Guidelines for Safe Practice in Managing Recreational Waters, page 150 (WHO, 2003))

Probability of adverse health effects	Guidance level or situation	How guidance level derived	Health Risks	Typical Actions
Relatively low	20,000 cyanobacterial cells/ml or 10 µg/ chlorophyll-a/liter with dominance of cyanobacteria	From human bathing epidemiological study	Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness	Post on-site risk advisory signs Inform relevant authorities
Moderate	100,000 cyanobacterial cells/ml or 50 µg chlorophyll-a/liter with dominance of cyanobacteria	From provisional drinking-water guideline value for microcystin-LR [= 1 µg/L] and data concerning other cyanotoxins	Potential for long-term illness with some cyanobacterial species Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness	Watch for scums or conditions conducive to scums Discourage swimming and further investigate hazard Post on-site risk advisory signs Inform relevant authorities

High	Cyanobacterial scum formation in areas where whole-body contact and/or risk of ingestion/aspiration occur	Inference from oral animal lethal poisonings Actual human illness case histories	Potential for acute poisoning Potential for long-term illness with some cyanobacterial species Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness	Immediate action to control contact with scums; possible prohibition of swimming and other water contact activities Public health follow-up investigation Inform public and relevant authorities
*Actual action taken should be determined in light of extent of use and public health assessment of hazard.				

As most cyanobacteria produce some combination of cyanotoxins, and as the most commonly found cyanobacteria produce microcystins in particular, the trend in monitoring has often used cyanobacterial cell counts as a proxy for toxin concentrations. This stems from the higher cost for toxin analyses, the small number of laboratories performing the analyses, and the limitations in the research to be able to quantify all of the different cyanotoxins. The World Health Organization has used a number of studies to estimate an approximate microcystin concentration that would be expected from a given cell density of *Microcystis aeruginosa*. Their guidelines also state that levels of 4 μg/L and 20 μg/L would be expected at the relatively low and moderate risk levels respectively. The WHO also points out that if another species other than *M. aeruginosa* dominates, the microcystin levels could be quite different. Microcystin levels could be doubled for a bloom of *Planktothrix agardhii* or significantly decreased for blooms of other microcystin-producing genera such as Anabaena. Other studies in the literature indicate that there can be substantial variability in the toxin production by *M. aeruginosa*. Different strains of the same cyanobacterial species can vary in their genetic capacity to produce toxin. Some blooms of *M. aeruginosa* may in fact produce little to no microcystin. Other strains may be neurotoxic, hepatotoxic, or both neuro- and hepatotoxic. This may be related to a variety of genetic and environmental variables that can alter the behavior of *M. aeruginosa* strains, as well as determine when genes for microcystin synthesis are activated (Zurawell *et al.*, 2005). When possible, it is

ideal to identify and enumerate the cyanobacteria species, and to also analyze and quantify the presence of microcystins. When this is not possible, cyanobacterial cell counts may be used as an indicator for toxin concentrations as a prudent precaution.

In 2005, an Oregon statewide interagency cyanobacteria task force recommended issuing advisories at a lower guideline of 40,000 cells/mL if cell populations are dominated by *Microcystis* and *Planktothrix* (Stone & Bress, 2007). This lower guideline is based on the premise that these two genera are more likely to produce microcystin toxin compared to other genera, such as *Anabaena* (Chorus & Bartram, 1999, Codd *et al.*, 2005) and the observation that almost all *Microcystis* strains are toxic (Carmichael, 1995). To derive the guideline of 40,000 cells/ml, a risk assessment approach was employed based on recreational exposure to microcystin toxin to a child (Appendix 6).

Currently, no tolerable daily intake or reference dose has been established for anatoxin-a, prohibiting the quantitative approach that was used for microcystin. Detection of anatoxin-a or any other cyanotoxin in recreational waters should be handled on a case-by-case basis, involving expert consultation for public health and lake access decisions.

If a water body is posted because of a large blue-green algae bloom, the signage should address the presence of cyanobacteria in general. This is because it is as yet unclear whether all important cyanotoxins have been identified, and because the health outcomes that may be observed after recreational exposure (particularly irritation of the skin and mucous membranes) are probably related to other components of cyanobacteria, such as allergens and irritants.

<u>Suggested Signage and Information</u>

If the decision is made to post a recreational water body, signage should be large enough to be seen and read by the recreating public. Signs should be placed at access points to the affected water body or other appropriate locations. (See examples of suggested signage, Appendix 2).

When a posting, closure, or other restriction or public notification occurs in a water body that is used as a source of drinking water by a public water system, the local health officer should notify the manager of the public water system.

Other means of public information and education may be appropriate, including brochures, press releases and public service announcements. Examples of brochures are attached in Appendix 3.

Because the symptoms of exposure to cyanobacterial toxins may be similar to those caused by other disorders or diseases, local health officials may want to

notify local doctors, hospitals, and veterinarians of the presence of toxic cyanobacteria.

Doctors and veterinarians may not be familiar with the symptoms of toxin exposure in humans, pets, and livestock. Symptoms of toxin poisoning may be misdiagnosed without proper information on their acute and chronic effects.

Facts sheets may be sent to local doctors, hospitals, clinics and veterinarians with information about the occurrence and symptoms of toxin exposure. Example facts sheets are attached in Appendix 4 and 5.

<u>Lifting Advisories</u>

In certain situations when chronic blue-green algae blooms occur, as with certain ocean storm drains with chronic microbiological contamination, long-term posting in lieu of monitoring may be a reasonable approach.

Cyanotoxins are found within the cell during most of a bloom event. Toxins may be released into the water when the cells die and lyse. The released toxin will dilute and eventually degrade over time. The risk of exposure to toxins may be greater immediately following the peak of a bloom through extracellular release, even though the producer cells (i.e. cell density) are absent or found in low numbers (Lawton et al., 1994). An additional risk factor is that the water will appear more suitable for recreational activities as clarity increases, thus elevating the potential for exposure during this period.

Stone and Bress (2007) recommend that advisories be lifted two weeks after cell counts fall below recommended thresholds established in the "Posting Warning Notices and Issuing Advisories" section of this guidance and if there is evidence of a declining bloom. Additionally, if toxin analyses are being conducted, then advisories may be lifted one week after toxin results are below the guideline levels. Stone and Bress also suggest that under extreme blooms, e.g., when an illness from cyanobacterial toxins exposure occurs, an official closure of the water body may be appropriate.

If the dominant species of blue-green algae is known to produce anatoxin-a and microcystin, it is recommended that both toxins be tested prior to lifting an advisory.

The advisory should remain in place until a final quantitative sample confirms the decreasing trend of potentially toxigenic blue-green algae and restrictions should remain in place whenever scums are visible. In some situations there may be reason, such as reported illness and/or persistence of the toxin, to prolong the advisory beyond the recommended waiting period.

Authorities

State and Regional Water Boards

The Water Boards are authorized to require others to post health warnings or to post the warnings themselves under appropriate circumstances. Under Water Code section 13304, the Water Boards can issue a Cleanup and Abatement Order directing anyone responsible for discharging wastes that have caused an algae bloom to post health warnings. Posting is a pollution or nuisance "abatement" activity authorized under section 13304. Under Water Code section 13304(b), the Water Boards may do the posting themselves under appropriate circumstances, for example, if there is no readily identifiable responsible party or urgent action is needed.

If the algae bloom is not the result of waste discharges, then the Water Boards can use Water Code section 13225(d) and/or (g) to formally notify the local health officer of the health threat and officially request that the health officer post health warnings. Subsection (d) provides that the Regional Water Boards shall request federal, state, and local agencies to enforce their respective water quality control laws. Subsection (g) directs the Regional Water Boards to report any case of suspected contamination to the State Water Board and the appropriate local health officer. Further, if more assertive action is necessary, the Regional Water Boards can require the local health officer, under Water Code Section 13225(c), to investigate the problem and report back to the Regional Water Boards on the results of the investigation and actions that the health officer will take to protect the public.

The Regional Water Boards can coordinate the posting of health warnings under Water Code section 13225(a). This subsection requires the Regional Water Boards to "[c]oordinate with the state board and other regional boards, as well as other state agencies with responsibility for water quality, with respect to water quality control matters, including the prevention and abatement of water pollution and nuisance."

Under Clean Water Act section 303(d), the Water Boards are required to identify and list water bodies that are impaired due to pollutants and to develop plans to address the impairments. Appropriate measures to address the impairments may include posting for public health protection."

Local Health Departments

Health and Safety Code 101030. The county health officer shall enforce and observe in the unincorporated territory of the county, all of the following:
(a) Orders and ordinances of the board of supervisors, pertaining to the public health and sanitary matters.

(b) Orders, including quarantine and other regulations, prescribed by the California Department of Health Services.
(c) Statutes relating to public health.

Health and Safety Code 101040. *The county health officer may take any preventive measure that may be necessary to protect and preserve the public health from any public health hazard during any "state of war emergency," "state of emergency," or "local emergency," as defined by Section 8558 of the Government Code, within his or her jurisdiction.*

"Preventive measure" means abatement, correction, removal or any other protective step that may be taken against any public health hazard that is caused by a disaster and affects the public health.

Funds for these measures may be allowed pursuant to Sections 29127 to 29131, inclusive, and 53021 to 53023, inclusive, of the Government Code and from any other money appropriated by a county board of supervisors or a city governing body to carry out the purposes of this section.

The county health officer, upon consent of the county board of supervisors or a city governing body, may certify any public health hazard resulting from any disaster condition if certification is required for any federal or state disaster relief program.

<u>California Department of Health Services</u>

California DHS regulates public water systems under the California Safe Drinking Water Act (Health and Safety Code Section 116270, et seq.), and, via primacy, the federal Safe Drinking Water Act. DHS laws and regulations include:

(1) Health and Safety Code Sections 100275, 115880, 116075, and 116080 authorize the Department of Health Services to adopt regulations pertaining to beach safety (the latter two are specific for ocean waters and bays).

(2) DHS' regulations for ocean beaches and ocean water contact areas for recreational use are published in Title 17 of the California Code of Regulations, in Group 10. Sanitation, Healthfulness and Safety of Ocean Water-Contact Sports Areas. beginning with Section 7952.

(3) DHS' regulations for public beaches are in Title 17 of the California Code of Regulations, Group 10.1 Sanitation of Public Beaches, beginning with Section 7972. They provide definitions of terms, and address the provision of water supply, toilets and sanitary facilities, maintenance, refuse handling, campsites and animals.

(4) DHS also has general authority in public health matters:

Health and Safety Code Section 131056 states that the department may commence and maintain all proper and necessary actions and proceedings for

any or all of the following purposes: (a) To enforce its regulations. (b) To enjoin and abate nuisances dangerous to health. (c) To compel the performance of any act specifically enjoined upon any person, officer, or board, by any law of this state relating to the public health. (d) To protect and preserve the public health. It may defend all actions and proceedings involving its powers and duties. In all actions and proceedings it shall sue and be sued under the name of the department.

(5) Health and Safety Code Section 131080 states that the department may advise all local health authorities, and, when in its judgment the public health is menaced, it shall control and regulate their action.

Resources for Additional Information

Each county in California (as well as the cities of Berkeley, Long Beach, Pasadena, and Vernon) has a health department led by a Director or Health Officer. Their contact information is available through the directory published by the California Conference of Local Health Officers: http://www.dhs.ca.gov/cclho/.

Local telephone book blue government pages also list phone numbers for the local city or county health department.

World Health Organization Guidelines for Drinking Water Quality, 3rd Edition:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html

World Health Organization Guidelines for Safe Recreational Waters, V. 1 – Coastal and Fresh Waters:
http://www.who.int/water_sanitation_health/bathing/srwe1-chap8.pdf

World Health Organization's "Toxic cyanobacteria in water: A guide to their public health consequences, monitoring and management":
http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/index.html

California Department of Health Services:
http://www.dhs.ca.gov/bga

State Water Resources Control Board:
http://www.waterboards.ca.gov/bluegreenalgae/index.html

National Center for Disease Control:
http://www.cdc.gov/hab/cyanobacteria/facts.htm

Cyanobacteria Image Galleries
http://www-cyanosite.bio.purdue.edu/images/images.html
http://botit.botany.wisc.edu/images/130/Bacteria/Cyanobacteria/

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Appendix 1
Monitoring

Assessing the risk posed by toxic cyanobacteria, or the potential for development of Cyanobacterial blooms, and linking this to effective measures for the protection of public health within available resources, is complex. The responses to long-term situations will be different from those where there is an immediate threat.

Public health concerns will probably drive objectives when developing monitoring plans for cyanobacterial blooms. Before data is collected public health officers should develop a plan to communicate those data to the public. Example objectives could include:

- Assessing and responding to public health concerns,
- Assessing potential causes of the bloom and identifying patterns in bloom development,
- Comparing monitoring results with established alert levels, or
- Tracking the effects of management changes.

Monitoring should focus primarily on the protection of human health and secondarily on the health of pets and livestock. Assessing the potential hazard at recreational water bodies can be complicated if numerous access points are present allowing people and animals to enter or move around the water. Blue-green algae concentrations often rapidly change due to wind or other factors. Scums can generally be assumed to present the greatest risk to recreational bathers. Monitoring should include samples that represent worst-case conditions in areas in which people and animals are most likely to contact the water. Analyses of samples that represent areas of the lake without a visible cyanobacterial bloom can also be helpful for risk communication to the public.

An effective design for bloom evaluation and monitoring should collect data that could answer questions such as:

1. Where is the bloom most concentrated? Does that change based on wind direction?
2. What are the dominant species in the bloom?
3. Are the cyanobacterial cells producing toxins? At what concentration?
4. Are toxin concentrations changing with bloom growth and die-off?
5. Are there other associated concerns or patterns – pH, dissolved oxygen (DO), taste and odor problems?

Sampling Frequency and Number of Samples

The location of samples and the number of samples taken depends upon both the specific needs as determined by recreational use and available funding. If funding is limited, sampling may need to be focused on near shore waters in areas where wading and swimming might occur. If resources allow, sampling far from shore may be desired, in order to assess risks to water skiers and other similar the recreating public.

Depending on funding and the reasons for sampling (e.g., resource management, public health protection), samples from within the bloom, from areas at various distances from the bloom, and areas appearing to be without bloom may be appropriate. Samples at various depths may also be desirable. In addition, chemical analysis can complement biological analysis by providing information on the cause of a bloom. Nutrient data to calculate the ratio of nitrogen (N) to phosphorus (P) before and during the bloom may be useful for evaluating whether or not a low N:P ratio (in general, lower than 10:1 molecules) may be one of the causes of the bloom (WHO, 1999, Chap. 2).

Sampling frequency will depend on visible changes in a bloom, public health concerns, the desired schedule for risk communication, project budget, and likely analytical turn-around times.

Sampling Methods

Sample collection

Samples of water containing blue-green algae should be taken using methods specified by the analytical laboratories. Sample collectors should take special precautions when gathering samples as some cyanotoxins may cause skin rashes following dermal exposure.

Algal sampling

Sample collection can be qualitative (a plankton net) or quantitative (a whole water sample of known volume). The online document titled "Blue-Green Algae (Cyanobacteria) in Inland Waters: Assessment and Control of Risks to Public Health," located at http://www.scotland.gov.uk/library5/environment/bgac-01.asp, contains a guide for sampling blue-green algae. It's called, "Recognition and identification of blue-green algal blooms and methods for sampling Annex E, " and it is located at: http://www.scotland.gov.uk/library5/environment/bgac-18.asp.

Qualitative net sampling provides a sample that is representative of a larger water volume than a specific volume of water sampling.

Sampling for toxins

Water samples should be taken in pre-cleaned glass containers equipped with Teflon-lined screw tops. The volume of sample needed is about 250 milliliters (mL), but collection volume and methods of storing and shipping samples should be discussed with the laboratory performing the analyses.

Analytical Methodologies and Laboratory Access

Blue-Green Algae Speciation Method

There is not a standard method, *per se*, for speciating cyanobacteria. There are, however, accepted methods for quantifying the numbers of each species in a known volume of sample. These require a settling chamber (and approximately 24 hours for the cells in the sample to settle), a standard cell counter like a Sedgwick-Rafter or Palmer-Maloney, and an inverted microscope. Typically a 1-milliliter (mL) sample of the settled mass is placed in the counting cell and all cells are counted and identified to genus and species.

Alternatively, a qualitative approach can be used and is often the most practical for detecting low concentrations of cells, as well as for increasing sample throughput. Qualitative observations could involve a quick field screening of a sample for determining the relative abundance of each species. This process would involve training staff to perform microscopic evaluations in the field or at a local laboratory facility. A time series of qualitative samples can provide the trend data necessary to detect an imminent bloom.

Manuals and guides for blue-green algal speciation are available and can be provided if needed.

Toxin Quantification

There are currently no US EPA approved methods for identifying and quantifying cyanotoxins in recreational or drinking water. However, US EPA has put a high priority on studying these compounds as part of its drinking water unregulated contaminants monitoring requirement (UCMR) program (see (Maizels & Budde, 2004) and http://www.epa.gov/nerl/research/2005/g2-3.html).

Cyanotoxin analysis currently available through commercial laboratories uses either liquid chromatography-mass spectrometry (LC-MS) or enzyme-linked immunosorbent assay (ELISA). The LC-MS specifically identifies individual toxins such as microcystin-LR (the most toxic of approximately 60 different microcystin congeners), while the ELISA method determines multiple types of microcystins. The capital costs of the LC-MS are quite high, thus, many otherwise well-equipped water testing laboratories lack the needed instrumentation.

Laboratories

The number of laboratories available for blue-green algae speciation, cell counting, and toxin analysis is quite limited.

These analyses may be quite costly, ranging from $150 for species identification and cell counts, and from $150 to $350 for individual toxin analyses by LC-MS. The ELISA determination of microcystins is less expensive, approximately $125-$150 per sample.

Laboratories providing cyanobacterial analysis at the time of publication include the following [this list will be updated as appropriate in future drafts of this document; laboratories capable of these analyses should be encouraged to contact the SWRCB to be included in updates of this list]:

Species Identification

GreenWater Labs, previously Cyanolabs, in Florida. ; Mark Aubel, (386) 328-0882, **http://www.cyanolab.com**

Note: Laboratories that contract with wastewater utilities often have this expertise.

Microcystin and Anatoxin Analysis

GreenWater labs (previously Cyanolabs), in Florida. LC-MS for the toxins produced by Cylindrospermopsis and Aphanizomenon and an ELISA method (qualitative and quantitative) for microcystins. Mark Aubel, (386) 328-0882, http://cyanolab.com;

California Animal Health & Food Safety Laboratory System, Davis, (530) 752-8700, Tests water and animal stomach contents. http://www.cahfs.ucdavis.edu/index.php

California Department of Fish and Game, Fish and Wildlife Water Pollution Control Laboratory, tissue analysis, David B. Crane (916) 358-2859, dcrane@ospr.dfg.ca.gov

US EPA Region 9 Lab, 1337 S. 46th St., Bldg. 201, Richmond, CA 94804
Contact: Andrew Lincoff

Field testing

Research is ongoing for ELISA -based and genetic-based field test kits. There are commercial test kits (ELISA format) that may be suitable for use in local public health laboratories: http://www.envirologix.com/library/et022spec.pdf

Appendix 2

Signage

Example of informational warning sign from the Klamath BGA Workgroup:

WARNING

BLUE GREEN ALGAE PRESENT IN THE KLAMATH RIVER

We recommend the following precautions:

1. **Keep pets, especially dogs, out of areas containing visible concentrations of algae and do not allow them to drink river water.**

2. **Avoid swimming or wading in areas with visible concentrations of algae.**

3. **Swimmers should shower and pets be rinsed off with tap water soon after swimming. Supervise children at all times.**

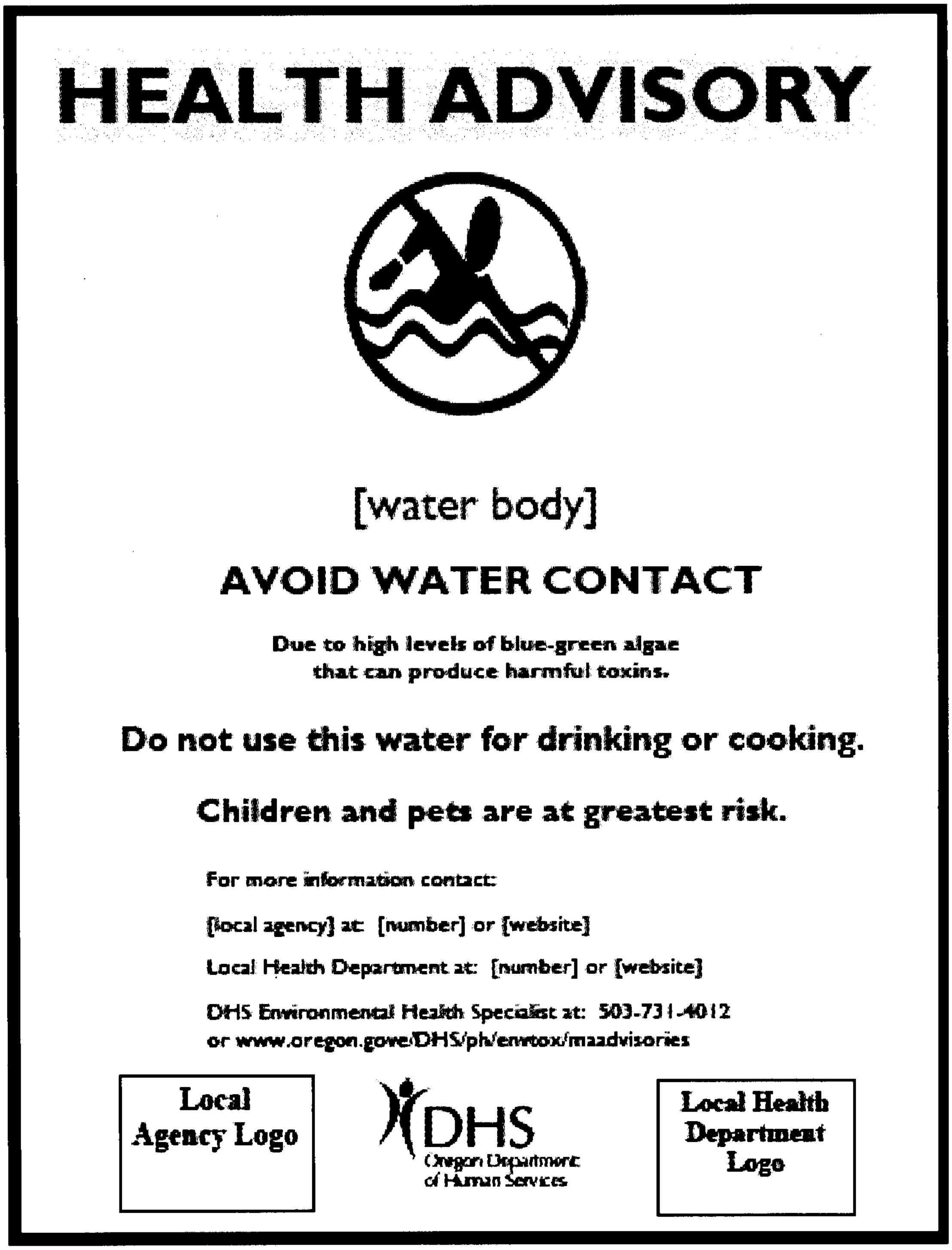
4. **Fish may be consumed after removing guts and liver, and rinsing fillets in tap water.**

5. **Do not drink or cook with the river water.**

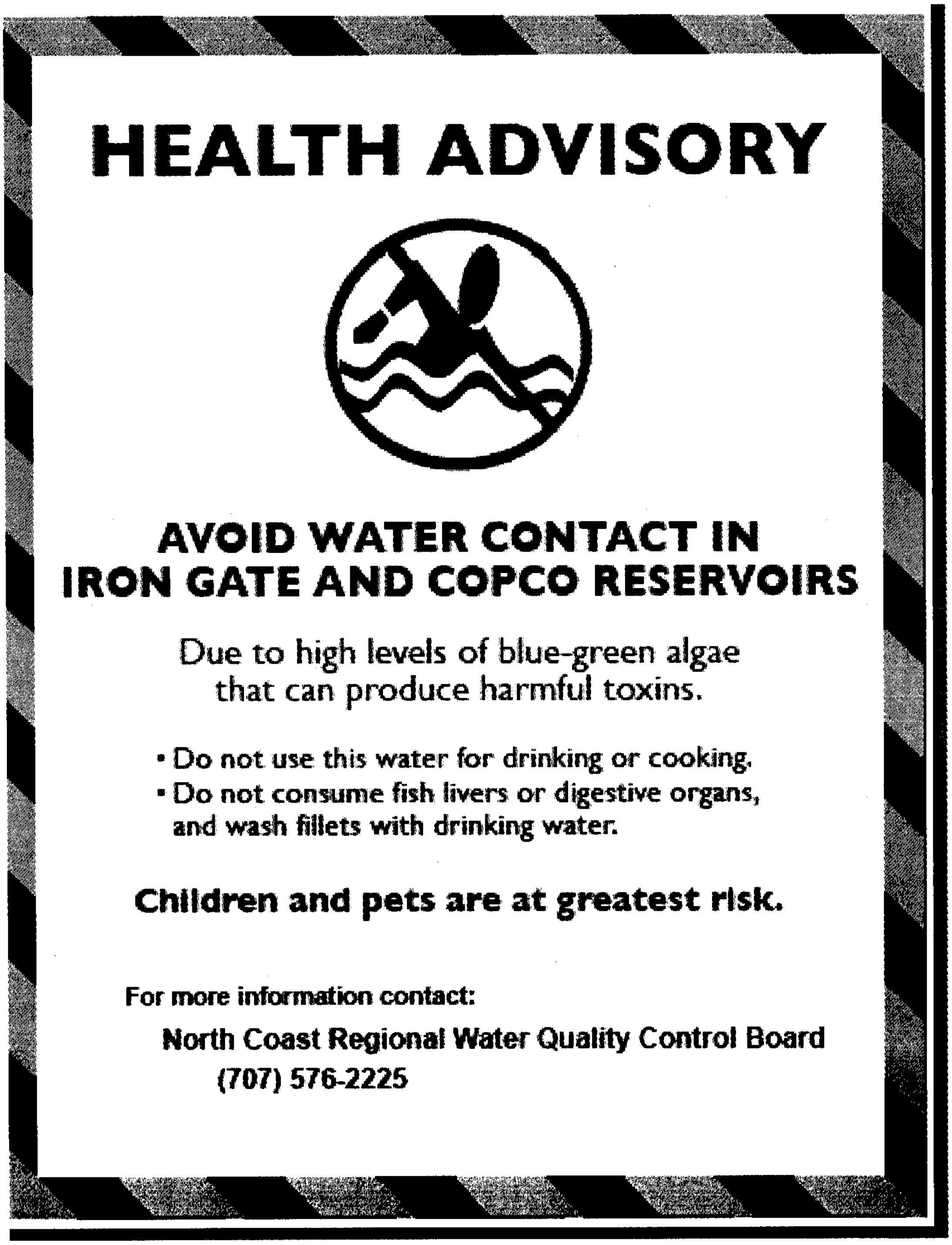
Presence of blue green algae in the Klamath River during the summer and fall can result in dangerous buildup of toxins in the water. However, activities near the water such as camping, picnicking, biking and hiking are safe.

If you have questions or comments, please contact:
TRIBAL HOTLINE NUMBER (707) 482-1350 ext. 367
Division of Environmental Health
(707) 445-6215 or 1-800-963-9241
OR visit the CA Dept of Health Services website:
http://www.dhs.ca.gov/bga

Example of advisory sign from Oregon:



Example of advisory sign from the North Coast RWQCB:



Appendix 3
Public Brochures

Example of Public Brochure from the Oregon Department of Health:

Blue-Green Algae Blooms

What are blue-green algae? Blue-green algae are simple plants that occur naturally in water and wet areas.

What is a blue-green algae bloom? A bloom is a rapid buildup of algae that creates a green, blue-green, white or brown color on the surface of the water. They are often found in standing water in lakes, reservoirs, ditches, ponds, streams, and rivers and the algae may be found near the shore due to wind or waves.

What causes blooms? Warm, calm water and nutrients contribute to the rapid growth of algae. Blooms can occur anytime of the year, but are most common between June and September.

How do I know if a bloom is toxic? Only a few types of blue-green algae are known to produce toxins. Many of the lakes and reservoirs in the state are monitored for toxic algae blooms and the public is notified when these blooms occur. However, it is important to always look for the signs of an algae bloom before you enter the water.

How dangerous is toxic algae? If toxic algae is swallowed it may cause diarrhea, nausea, cramps, fainting, numbness, dizziness, tingling, and paralysis. Skin contact can cause rashes or irritation. Children and pets are at greatest risk.

What should I do if I see a bloom? When a bloom is present it is best to stay out of the water and to keep pets away. If you do contact the water, wash thoroughly with a clean source of water. Do not use the affected water for drinking or cooking because toxins cannot be removed with filtration, boiling or chemical treatments. However, activities near the water such as camping, picnicking, biking, and hiking are safe.

What about fishing? Eating fish caught during a bloom may pose a health risk. For additional information about fish consumption contact the Department of Human Services.

For more information visit
www.oregon.gov/DHS/ph/envtox/maadvisories
Or call DHS at (503) 731-4012

Fact Sheet approved by Humboldt, Mendocino and Del Norte County Environmental Health Departments:

Blue Green Algae Health Concerns—North Coast Region of California

What are blue green algae? Blue green algae are actually a type of ancient bacteria commonly found in water or wet areas.

What is a blue green algae bloom? When conditions are right, algae can rapidly build up or "bloom" on the surface of reservoirs, rivers, creeks, lagoons, lakes and ponds. The bloom can be green, blue green, white or brown, and may look like a floating layer of scum or paint.

What causes blooms? Warm, slow-moving waters that are rich in nutrients like fertilizer or manure runoff can cause algae growth. Blooms can occur at any time, but are most common in late summer or early fall.

How do I know if a bloom is toxic? Only a few types of blue green algae are known to produce poisons. Most blooms of algae in our region are made up of harmless green algae. North coast counties do not have the resources to test their many water bodies for these toxins. (An exception is the Klamath River, which has been regularly tested for blue green algae toxins by tribal and federal agencies over the summer season for the last few years). Often, the first sign that a bloom is toxic is a dog that has gotten sick after swimming in stagnant water. **Always look for the signs of an algae bloom before you enter the water, or before you let your children or pets enter the water.**

How dangerous is toxic algae? If toxic algae touches your skin, or you accidentally inhale or swallow water containing the toxin during recreation, you could get a rash or an allergic reaction, or develop gastrointestinal problems. The long-term effects of these exposures are not well known, but children and pets are at greatest risk. Since 2001, 9 dog deaths following contact with fresh water bodies in Humboldt and Mendocino Counties are suspected to have been caused by blue green algae poisoning. Dogs can be exposed to particularly high levels of toxins by licking blue green algae off their fur after a swim. No documented incidents of human poisoning from blue green algae have been reported in any of the three north coast counties.

What should I do if I see a bloom?

- Stay out of areas where the water has foam, scum, or mats of algae. Keep children and pets out of such areas at all times. If you or your pets swim or wade in water with algae, rinse off with fresh water as soon as possible. Always warn young children not to swallow **any** water, whether or not you see signs of algae.
- Do not drink or cook with this water. Even if you boil or filter it, the toxins can persist.
- Do not let livestock swim in or drink from areas where you see foam, scum, or mats.
- Get medical treatment right away if you think that you, your pet or your livestock might have been poisoned by blue green algae toxins.

What about fishing and other activities? Eating fish caught during a heavy bloom can pose a health risk. Always remove the guts and liver, and rinse fillets in tap water

before eating the fish. Other activities near the water such as camping, picnicking, biking and hiking are safe.

Report pet deaths/illnesses following water contact, or unusual numbers of dead or distressed wildlife along the shoreline to:

- Humboldt County – Harriet Hill, REHS, 707-445-6215 or 1-800-963-9241
- Mendocino County – John Morley, REHS, 707-463-4466
- Del Norte County – Peter Esko, REHS, 707-464-3191

Find more information at the CA Department of Heath Services website*:* <u>http://www.dhs.ca.gov/ps/ddwem/bluegreenalgae/default.htm</u>

Example of public news release from Siskiyou County Public Health:

News Release

Siskiyou County Public Health

NUMBER: ALG 06-02
FOR RELEASE:
http://www.co.siskiyou.ca.us/phs

DATE: August 3, 2006
CONTACT: Terry Barber

The summer recreation season is upon us. County residents and visitors are visiting our local waterways to enjoy camping, boating, kayaking, and river rafting activities.

The Siskiyou County Public Health Department reminds residents and visitors that Irongate Reservoir, Copco Lake and Lake Shastina are known to have seasonal blooms of blue-green algae (cyanobacteria). Irongate Reservoir and Copco Lake are currently experiencing a bloom. Blooms typically occur between June and October when temperatures rise and water conditions are favorable for algal growth.

Samples from Irongate Reservoir and Copco Lake taken in late July indicate high algae cell counts and visible algal scums along the shoreline. Sampling from previous years indicates that these algae are capable of releasing toxins that are potentially harmful to human health. Related to those blooms, Siskiyou County provided brochures at the affected water bodies and provided public service announcements about potential health concerns.

Blue-green algal blooms are common phenomena that occur world wide. The State of California has embarked upon a process to evaluate the potential health risks associated with blue-green algal toxins, determine appropriate water sampling and monitoring procedures, identify strategies to control toxic blooms, and to better inform the public about health and environmental concerns. Siskiyou County is an active participant in this statewide effort and will continue to keep abreast of information and issues concerning toxic blue-green algal blooms.

While there have been no documented cases of human illness associated with blue-green algae in California, studies around the world show that recreational exposures to toxic blue-green algae might result in eye irritation, allergic skin rash, mouth ulcers, vomiting and diarrhea, and hay-fever like symptoms. There

is little information available about the potential human health effects of long-term exposure to blue-green algae.

The presence of blue-green algae in a water body does not necessarily mean toxins are always present. However, identifying the presence of toxins is an expensive and difficult process and one that may involve many days to weeks before results are available. Therefore, it is prudent for recreational users to adhere to the following precautions with regard to blue-green algae blooms in Siskiyou County water bodies:

- Avoid wading and swimming in water containing visible blooms or water containing algal scums or mats.
- Carefully watch children to ensure that their exposure and accidental water ingestion is minimized. Because of their small body size and weight, children who ingest a small amount of water can receive a higher relative exposure to toxic substances than adults who ingest the same amount.
- Do not drink, cook or wash dishes with untreated surface water under any circumstances. In addition to blue green algal toxin concerns, open surface waters can contain harmful bacteria and parasites.
- If you accidentally swallow water from a bloom and experience one or more of the following symptoms you should contact your physician and the Public Health Department.
    - Stomach cramps
    - Vomiting
    - Diarrhea
    - Fever
- Fish caught in these reservoirs may be consumed after removing guts and liver, and rinsing filets in tap water.

In addition, residents and visitors are reminded that domestic animals and livestock can be affected by blue-green algal blooms. There are documented animal poisonings and deaths associated with exposure and consumption of algal toxins. Special care should be taken to ensure that animals do not drink the water or swim through heavy scums or mats. Consumption of algal toxins occurs when animals lick their fur after wading/swimming in blue-green algal blooms.

The public may contact the Siskiyou County Public Health Department for additional information by calling (530) 841-2100. Information is also available by visiting our website: http://www.co.siskiyou.ca.us/phs. For information about the State of California's activities related to blue-green algae blooms, visit these web sites:

- Department of Health Services: http://www.dhs.ca.gov/bga
- State Water Resources Control Board: http://www.waterboards.ca.gov/bluegreenalgae/index.html

Appendix 4
Information for Physicians

The Centers for Disease Control and Prevention's Harmful Algal Blooms website at:
www.cdc.gov/hab/cyanobacteria/about.htm includes a short section on health effects and CDC's efforts to support research on human health effects from recreational water exposure to cyanobacteria.

CDC's cyanobacterial fact sheet:
http://www.cdc.gov/hab/cyanobacteria/pdfs/about.pdf

Appendix 5

Sample fact sheet for veterinarians

Blue Green Algae (BGA) - Detailed Fact Sheet

For Distribution to Animal Health Workers

Prepared by: Harriet Hill, Humboldt County Division of Environmental Health, revised June 2006

INTRODUCTION

The blue green algae (BGA), now considered to be a type of bacteria called cyanobacteria, are an ancient family of photosynthetic organisms. The fossil record shows that BGA has existed for around 3.5 billion years. It is thought to be one of the first organisms able to carry out photosynthesis. BGA also are noted for their ability to "fix" gaseous nitrogen, and some produce deadly toxins as secondary metabolites. BGA can produce nervous system poisons (neurotoxins), liver poisons (hepatotoxins), or compounds that cause allergic responses (lipopolysaccharide endotoxins). BGA neurotoxins can kill animals within minutes by paralyzing the respiratory muscles, while the hepatotoxins can cause death within hours by causing blood to pool in the liver. The same BGA species can be toxic or nontoxic at different times.

Since the summer of 2001, 9 dog deaths following contact with water bodies in Humboldt and Mendocino Counties may have been caused by BGA poisoning, prompting the preparation of this fact sheet for animal health workers and other interested parties.

BGA BLOOMS

BGA periodically "blooms," that is, creates floating mats, forming what is commonly known as "pond scum." These blooms can be green, blue-green, white or brown. The occurrence of BGA toxins in the freshwater environment is unpredictable. Blooms may persist for up to seven days but the resulting toxins may last for weeks. BGA move up and down within the water column and thus may not always float to the surface. Currents and surface winds can push them toward the land, causing poison-filled cells to accumulate in a thick layer near the leeward shore. Low flow river conditions in the summer and fall may result in large build-ups of BGA. When algae cells die or are damaged, toxins may be released at levels harmful to humans, pets and livestock if they ingest water or algae.

Blooms are most likely to form when three conditions converge:

- the wind is quiet or mild
- the water is warm but not hot (60 to 86 degrees F, 18 – 25 ºC))

- the water harbors an abundance of the nutrients nitrogen and phosphorus (i.e., from agricultural or urban runoff, or failing sewage disposal systems).

EFFECTS OF BGA ON ANIMALS

There are numerous reports of thirsty domestic animals and wildlife consuming fresh water contaminated with toxic BGA and dying within hours from neurotoxicity or hepatotoxicity, or developing sublethal chronic liver disease. Canine deaths from BGA exposure include dogs dying from neurotoxic exposure in lakes in Scotland, from drinking BGA-contaminated lake water in Saskatchewan, Canada, and from contact with a lake in Idaho. Reported neurological symptoms included stumbling and falling, followed by an inability to rise, elevated heart rate, foaming at the mouth, howling, tremors, loss of bowel control, eyes rolling back into the head, and seizures.

The amount of BGA-tainted water needed to kill an animal depends on many factors but typically the volume ranges from a few ounces to several gallons. Thirsty animals are often undeterred by the foul smell and taste of contaminated water. Additionally, dogs can consume large quantities of BGA by licking their fur after swimming in a bloom.

Recent Dog Deaths Following Contact With Big Lagoon and South Fork Eel River

From July through October 2001, 5 dogs died after swimming in Big Lagoon, mostly in the northeastern boat launch area known as the "Yacht Club." Symptoms included severe gastrointestinal distress, such as vomiting, bleeding, diarrhea and dehydration, and elevated liver enzyme levels. A pathology report found massive liver damage in one of the dogs. Two other dogs became ill after swimming in the lagoon and showed heightened liver enzyme levels. The onset of symptoms was within twelve hours and deaths occurred 2 to 4 days later. One dog had been covered in green slime after swimming in the lagoon. Water samples taken from Big Lagoon in November of 2001 (11/9/01), approximately one month after the last dog death on 10/7/01, were tested for microcystins, and found to be negative for this BGA hepatotoxin. Since 2001, no dog illnesses or deaths that could be attributed to BGA were reported from Big Lagoon. The deaths in 2001 may have been associated with the following factors: 1) heavy nutrient loading because the lagoon did not breach to the ocean during the winter, and 2) unusually warm weather.

In the summer of 2002, 3 dog deaths were reported after contact with the South Fork of the Eel River. Near Standish-Hickey State Park in Mendocino County, 2 dogs died within a few minutes of swimming in the river, and another dog died after swimming near Tooby Park in Garberville in Humboldt County. The vet who saw the dogs from Standish-Hickey stated that the animals had seizures

within 5-10 minutes of exposure to the water, and were dead within 15 minutes (Horvath, 2003).

A water sample taken a few days later in this area by Mendocino County Environmental Health Division (MEH) was found to contain *Anabaena* and *Lyngbya,* two toxin-producing BGA genera. A separate water sample was sent to the California Animal Health and Food Safety Laboratory System (CAHFS) who collaborated with the University of North Carolina (UNC) on the algae identification. The only toxin-producing BGA found by the UNC scientists in the sample was *Planktothrix. Planktothrix* and *Lyngbya* sometimes produce neurotoxins, including what are known as "paralytic shellfish toxins," while *Anabaena* may produce another neurotoxin called anatoxin.

CAHFS first analyzed the dogs' stomach samples for commonly encountered neurotoxins not associated with BGA, such as strychnine, metaldehyde and zinc phosphide: none were present. They then collaborated with Wright State University to analyze the stomach contents for BGA neurotoxins. The contents contained green plant-like material, and low concentrations of paralytic shellfish toxins. Most notably, the stomach contents contained very high concentrations of anatoxin-a, even though the water sample that CAHFS obtained did not include the BGA genera that produce this toxin. However, MEH staff had identified *Anabaena*, a genus that produces this toxin, in their water sample, and it is possible Anabaena was present only in one of the water samples, while the toxin was present in both. BGA and their toxins move with winds and currents, and a species of BGA could turn up in one water sample, but not another, depending on the time and location of sampling.

Therefore, based on analyses of the stomach contents of the dead animals, and the water sample collected from the river, CAHFS believes that the dogs were most likely poisoned by anatoxin-a, a neurotoxin produced by BGA (Puschner, 2003). This conclusion was supported by a recent survey of the South Fork Eel River by Denbo (2003), who observed *Anabaena* during the summer of 2003 on the river near the Humboldt/Mendocino County line.

In 2004, a dog that died in July shortly after swimming in the South Fork Eel River in Mendocino County near Indian Creek (Piercy) may have ingested BGA toxins; however, the dog was buried before this could be confirmed.

Guidelines for Veterinarians on Water and Necropsy Sample Collection:

Evidence of an algae bloom and/or a case history of sudden illness or death after water contact should raise suspicion of BGA poisoning. This may be supported if wild species (e.g., mice, muskrats, birds, snakes or fish) have also died in the vicinity. If BGA is suspected, samples should be taken as soon as possible, in the same location where an animal fell ill after swimming. **Any questions regarding sample collection from water sources or affected animals should**

be directed to the California Animal Health and Food Safety Laboratory (CAHFS), Toxicology Laboratory in Davis at 530-752- 6322. Samples should be collected as follows:

- Collect water samples in plastic water sample bottles or other plastic bottles. Collect samples in duplicates (freeze one sample, and refrigerate the other sample)
- Collect at least one liter of water for each sample.
- Send samples to the CAHFS Toxicology Laboratory, Davis on cold packs (call first).
- Undiluted, refrigerated samples can be examined microscopically using low power magnification. Microscopic examination may provide evidence that potentially toxic genera are present, not that harmful levels of toxins exist. On the other hand, the absence of visible algae does not exclude poisoning, especially if heavy rain or wind suddenly dispersed blooms.
- Specimens from affected animals: In general, the best samples for accurate diagnostic work are: vomitus, gastric lavage fluid, stomach content, liver, urine, and serum. Veterinarians can call the CAHFS Toxicology Laboratory in Davis for case-related consultations.

CONTACTS AND INFORMATION

Report algal blooms, pet deaths/illnesses following water contact and/or unusual numbers of any dead animals (including cattle) around water bodies to the appropriate County Environmental Health Division:
Humboldt County – **Harriet Hill, REHS, 707-445-6215 or 1-800-963-9241**
Mendocino County – **David Koppel, REHS, 707-463-4466**

For information on animal health contact the **State Animal Health Branch: 530-225-2140**
For information on specimen collection, laboratory testing and animal diseases contact the
CAHFS Toxicology Laboratory – **Drs. Birgit Puschner or Robert Poppenga, 530-752-6322**

See also the following web sites for details on drinking water and human health issues.

Department of Health Services:
http://www.dhs.ca.gov/ps/ddwem/bluegreenalgae/index.html

State Water Resources Control Board:
http://www.waterboards.ca.gov/bluegreenalgae/index.html

National Center for Disease Control:
www.cdc.gov/hab/cyanobacteria

Appendix 6

Risk Assessment for deriving quantitative guidance for blooms dominated by *Microcystis* or *Planktothrix* (from the Oregon Department of Human Services, Environmental Toxicology Program, 2005)

A focused risk assessment was conducted to characterize the risk associated with swimming in waters that are dominated by *Microcystis* or *Planktothrix* cyanobacteria.

The equation and parameters are described below:

$$\text{Concentration of toxin } (\mu g/L) = \frac{TDI \times BW}{IR}$$

where,

TDI (tolerable daily intake) = 0.04 µg/kg/day
BW (body weight) = 20 kg
IR (ingestion rate) = 0.1 L

The TDI was developed by the World Health Organization based on repeated oral administration of microcystin-LR in mice and effects on the liver (Fawell and James, 1994). A body weight (BW) of 20 kg was used to represent a child. An ingestion rate (IR) was based on EPA guidance for incidental ingestion of surface waters, in which 0.05 L is accidentally ingested per one-hour event (Dang, 1996). For this guidance, it was assumed that a child would swim for up to two hours in a single day.

Using the parameters described above, the equation results in 8 µg/L of microcystin toxin. According to World Health Organization guidance, 8 µg/L would correspond to approximately 40,000 cells/mL if *Microcystis* were the dominant species (Chorus & Bartrum, 1999). *Planktothrix* was included in the additional guidance, since it has the potential to contain higher endocellular microcystin compared with *Microcystis* (Codd et al., 2005).

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
NORTH COAST REGION

RESOLUTION NO. R1-2007-0028

Policy Statement in the Matter of Petition to the California Regional Water Quality Control Board, North Coast Region 1) To Order PacifiCorp to Submit a Report of Waste Discharge and/or 2) To Issue Waste Discharge Requirements, Including Prohibitions

WHEREAS, the California Water Quality Control Board, North Coast Region, (Regional Water Board) finds that:

1. The Karuk Tribe of California, Klamath Riverkeeper, Pacific Coast Federation of Fishermen's Associations and the Institute for Fisheries Resources (Petitioners) filed a petition dated February 20, 2007, requesting that the Regional Water Quality Control Board (Regional Water Board) order PacifiCorp to submit a Report of Waste Discharge (ROWD) for its discharges of Microcystis aeruginosa, microcystin toxin, and other pollutants from the Copco and Iron Gate Reservoirs, and issue waste discharge requirements (WDR) establishing appropriate restrictions and prohibitions safeguarding the beneficial uses of the waters of the Klamath River.

2. The Regional Water Board heard arguments and comments from Petitioners, PacifiCorp staff and the public on this matter during its regularly scheduled Board meeting on March 15, 2007, in Eureka, California. This item does not constitute an adjudicatory hearing and does not result in any action taken toward any party. This Resolution is informational only, and is not intended to bind PacifiCorp or any public agency with jurisdiction over PacifiCorp.

3. The Klamath River basin is a 12,680 square mile watershed originating in southern Oregon and flowing through northern California to the Pacific Ocean at Requa in Del Norte County, California. PacifiCorp owns and operates the 161-megawatt Klamath Hydroelectric Project, that includes a system of five dams located in Oregon and California. Copco and Iron Gate Reservoirs in California are located on the main stem Klamath River. Iron Gate Reservoir is located at river mile 190 with Copco Reservoir located at approximately river mile 198.

4. Blue-green algae are commonly found in many freshwater systems. Portions of the Klamath River system experience blooms of blue-green algae. Data show the presence of Microcystis aeruginosa and its toxin microcystin prompting health alerts by the US Environmental Protection Agency (US EPA), the State Water Resources Control Board (State Water Board), the Regional Water Board and the Karuk and Yurok Indian tribes for portions of the Klamath River. Blue-green algae thrive in warm, nutrient rich, slow moving to stagnant water bodies such as lakes, ponds, reservoirs and sluggish stream reaches having adequate sunlight for growth and reproduction; conditions present during the low-flow summer and fall seasons in Copco and Iron Gate reservoirs. By providing slow to stagnant pools of water, Copco and Iron Gate Reservoirs accumulate nutrients from upslope-upriver during summer and early fall seasons and cause increased

temperatures near the surface of the reservoirs, thereby promoting blooms of Microcystis aeruginosa and its associated toxin.

5. *The Water Quality Control Plan for the North Coast Region* (Basin Plan) designates the beneficial uses of water bodies within the North Coast Region, prescribes both narrative and/or numeric objectives determined by the Regional Water Board necessary to protect those beneficial uses, and includes implementation programs or actions designed to meet objectives and protect beneficial uses of water. The beneficial uses of water bodies, water quality objectives, and the state and federal antidegradation policies, together, constitute water quality standards.

6. The Klamath River and its tributaries support a number of existing and potential beneficial uses of water including:
    - municipal and domestic drinking supplies,
    - agricultural water supply,
    - industrial service water,
    - industrial processing water,
    - groundwater recharge,
    - navigation,
    - hydropower generation,
    - water contact recreation,
    - non-contact recreation,
    - commercial and sport fishing,
    - warm freshwater habitat,
    - cold freshwater habitat,
    - wildlife habitat,
    - rare, threatened or endangered species habitat,
    - marine habitat,
    - spawning, reproduction and/or early development,
    - shellfish harvesting,
    - estuarine habitat,
    - aquaculture,
    - subsistence fishing
    - Native American culture.

    A beneficial use is to be protected in any location that it is found, regardless of whether it is designated for a specific hydrologic unit in the Basin Plan. For example, subsistence fishing by Native Americans is not designated in Table 2-1 for the Klamath River hydrologic unit, yet this use is known to occur and must be protected.

7. The Basin Plan contains a narrative water quality objective that prohibits toxicity in concentrations that are toxic to human, plant, animal, or aquatic life. Compliance with this objective can be determined by a number of factors including growth anomalies. Growth anomalies leading to violations of the toxicity objective would include blooms of Microcystis aeruginosa and its toxin microcystin in amounts deleterious to the health of individuals.

8. Many species of blue-green algae produce toxic compounds known as cyanotoxins. Microcystin and anatoxin toxins are the two most common cyanotoxins encountered in California. Health risks from exposure to moderate concentrations of cyanotoxins during recreational activities can cause skin rashes, eye irritations, allergic reactions, gastrointestinal upsets and other illnesses. Exposure to high levels of microcystin in recreational and drinking water supplies is known to promote tumor growth and progressive chronic liver damage, and death in vertebrates.

9. The California Department of Health Services (DHS) has developed draft guidance recognizing the World Health Organization's (WHO) Tolerable Daily Intake and Guideline Values for microcystin toxin in water. The Tolerable Daily Intake is applicable to drinking water and Guideline Values relate to exposure during recreational water use. Risk levels and guidelines for blue-green algal cells and microcystin toxin include:
   - Drinking Water: 1 part per billion microcystin
   - Bathing and recreational waters:
   i. Low Probability of Adverse Health effects: 4 ppb microcystin or 20,000 cells/ml
   ii. Moderate Probability of Adverse Health Effects: 20 ppb microcystin or 100,000 cells/ml
   iii. High Probability of Adverse Health Effects: "Scum" on surface water.

10. The WHO and DHS Guidelines for a Moderate Probability of Adverse Health Effects of 20 ppb for microcystin toxin were exceeded in Copco and Iron Gate reservoirs. In the absence of promulgated, numeric water quality standards for this toxin, it is appropriate to consider exceedance of the WHO and DHS Guidelines for determining compliance with the narrative objective for toxicity. The Statewide Blue-Green Algae Group is working to standardize the methodologies for differentiating microcystin variants. More sampling and analyses will be conducted this summer.

11. The Basin Plan contains a narrative water quality objective that prohibits biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. Nutrient concentrations immediately upstream of Copco Reservoir and within Copco and Iron Gate Reservoirs are at levels that are biostimulatory and result in seasonal blooms of blue-green algae that cause nuisances and adversely affect beneficial uses. Some of the blue-green algae species, excluding Microcystis aeruginosa, identified in Copco and Iron Gate Reservoirs fix atmospheric nitrogen, thereby increasing nitrogen loads to the reservoirs. When the algae die, the nutrients within the algal cells are either stored in the bottom sediments within the reservoir or are released into the water column. These stored and/or released nutrients, especially phosphorus, often enhance nutrient enrichment in affected reservoirs, thus propagating additional blooms of blue-green algae in what the WHO calls a self-sustaining "feedback loop".

12. The Basin Plan contains a narrative water quality objective that prohibits tastes and odors in concentrations that impart undesirable tastes and odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely

affect beneficial uses. Recreational surveys by PacifiCorp showed that numerous recreational users of the two reservoirs objected to the odors caused by decaying blue-green algae.

13. The Basin Plan contains a narrative water quality objective that prohibits floating material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses. Blue-green algae blooms were documented and photo evidence shows accumulations of blue-green algae, almost exclusively Microcystis aeruginosa, in algal mats or scum on the waters surface and shorelines of the reservoirs which created nuisance conditions and adversely affected beneficial uses of water.

14. Evidence that beneficial uses of water in and downstream of Copco and Iron Gate Reservoirs are being adversely affected by blue-green algae include:
    - The exceedance of the DHS and WHO guidelines.
    - Visible and extensive algal mats.
    - Recreational water users' avoidance of swimming, wading, water-skiing, and fishing in areas of the reservoirs with excess blue-green algae blooms.
    - The Karuk tribe has offered anecdotal evidence that during traditional "whole body water immersion" ceremonies in "traditional locations and at traditional time frames," participants experienced skin rashes and gastrointestinal upsets. They believe it is from exposure to blue-green algal toxins.

15. Water quality data indicates that controllable water quality factors associated with Copco and Iron Gate Reservoirs are currently out of conformance with a number of Basin Plan water quality objectives. Water within and discharged from the reservoirs routinely exceed the following water quality objectives during the summer months:
    - Taste and Odor
    - Floating Materials
    - Biostimulatory substances
    - pH
    - Dissolved Oxygen
    - Toxicity

16. California Water Code section 13260(a) requires that any person discharging waste or proposing to discharge waste within any region that could affect the quality of the waters of the state, other than into a community sewer system, shall file with the Regional Water Board a ROWD containing such information and data as may be required by the Regional Water Board, unless the Regional Water Board waives such requirement. Discharges from the tailrace of a dam are considered a "discharge of waste" under the Porter-Cologne Water Quality Control Act. (*Lake Madrone Water District v. SWRCB*, 209 Cal.App.3d 163(1989).)

17. The Petitioners request that the Regional Water Board order PacifiCorp to file a ROWD and/or issue WDRs for Copco and Iron Gate Reservoirs, pursuant to the

California Water Code. These hydroelectric facilities are regulated under the Federal Power Act through a federal license issued by the Federal Energy Regulatory Commission (FERC). The federal license may contain certain conditions to adequately protect, mitigate and enhance beneficial public uses. In issuing the federal license, FERC has a duty to ensure that the project is best adapted to the Basin Plan. (16 U.S.C.A. § 803(a); see also 40 C.F.R. § 2.19 [the Basin Plan is part of California's comprehensive plan for the orderly and coordinated control, protection, conservation, development and utilization of the water resources of the state, and has been submitted for filing pursuant to Federal Energy Regulatory Commission (FERC) regulations].)

18. The United States Supreme Court has ruled that the Federal Power Act preempts state law. The state may not require a permit for a project already licensed by FERC except for proprietary rights to water. (See *First Iowa Hydro-Electric Cooperative v. FPC,* 328 U.S. 152 (1946); *California v. FERC,* 495 U.S. 490 (1990); *Sayles Hydro Associates v. Maughan,* 985 F.2d 451 (9th Cir. 1993).) Accordingly, the Regional Water Board cannot effectively require PacifiCorp to submit a ROWD and/or issue WDRs for the Copco and Iron Gate facilities, as requested by Petitioners.

19. States must ensure compliance with water quality standards and other appropriate requirements of state law through the statutory provisions of the federal Clean Water Act. (*PUD No. 1 of Jefferson County v. Washington Department of Ecology,* 511 U.S. 700 (1994).) Water quality certification by the state is required for any activity requiring a federal license or permit, which may result in any discharge to waters of the United States. (33 U.S.C. §1341.) Under section 401 of the Clean Water Act, a state may impose conditions on a federal project or a project required to obtain a federal permit, in order to certify that the project protects beneficial uses and meets water quality objectives as specified in the Basin Plan. (*S.D.Warren Co. v. Maine Board of Env'l. Protection,* 126 S.Ct. 1843 (2006) [unanimously upholding state's jurisdiction to regulate FERC hydroelectric facilities under section 401 of the Clean Water Act].)

20. In California, an application for water quality certification shall be filed with the Executive Director of the State Water Board, and notice provided to the Executive Officer of the Regional Water Board, when the proposed activity is associated with a FERC-licensed hydroelectric facility. (Cal. Code Regs., tit. 23, §3855.) The State Water Board is actively reviewing PacifiCorp's application for water quality certification, and both State and Regional Water Board staff have commented on the federal environmental document issued by FERC for the project. To date, PacifiCorp has not provided adequate information to provide sufficient information to certify that the project will comply with the Basin Plan. PacifiCorp has proposed to develop a reservoir management plan to address water quality impairment within the project area. The Regional Water Board will continue to participate in the relicensing process to ensure that the water quality certification conditions the project to meet Basin Plan requirements. Water quality plans, including PacifiCorp's reservoir management plan, should be developed in advance of license issuance so that implementation begins at the time the certification and license is issued.

21. Section 303(d) of the Clean Water Act requires states to identify waters that do not meet applicable water quality standards and further requires the US EPA to list such waters on the 303(d) impaired waters list. The Clean Water Act also requires that states or the US EPA establish Total Maximum Daily Loads (TMDLs) for waters on the impaired water list. Such TMDLs shall be established at levels necessary to implement applicable water quality standards with seasonal variations and a margin of safety.

22. The Klamath River in California is on the federal Clean Water Act section 303(d) list for elevated nutrients, elevated temperature, organic enrichment/low dissolved oxygen, and in the Klamath Glen hydrologic subarea (Klamath River below the community of Weichpec) for sedimentation/siltation. Reaches of the Klamath River in Oregon are on the 303(d) list for low dissolved oxygen, elevated temperature, chlorophyll a and pH. The Regional Water Board is in the process of developing TMDLs for these impairments, in cooperation with Oregon Department of Environmental Quality and with support from US EPA Regions 9 and 10.

23. Development of the Klamath River TMDLs is based largely on application of numerical water quality models, but also incorporates semi-quantitative and qualitative information linking pollutant source contributions to violation of water quality standards. Though these TMDLs are still in development, once the TMDL is implemented, it is expected that pollutant load and waste load allocations will result in reduced nutrient and organic enrichment of the Klamath River in California, as well as reduced stream temperatures. These improvements in water quality are expected to reduce the occurrence and frequency of blue-green algae blooms. It is anticipated that the TMDL will include water quality targets for chlorophyll a, blue-green algae cell density, and toxin concentrations that are protective of water quality standards.

24. Regional Water Board staff has begun the process of updating the 303(d) list. Data and information on the blue-green algae blooms and associated toxin concentrations in the Klamath River have been submitted to Regional Water Board staff for consideration in the listing process. Regional Water Board staff will consider recommending that the Regional Water Board list Copco and Iron Gate Reservoirs for blue-green algae and the microcystin toxin.

25. The Action Plan, which will implement the Klamath River TMDLs, will require that the water quality certification issued by the State Water Board ensures compliance with the Basin Plan. In addition, it may address any discharges upstream found to contribute to the blue-green algae problem in the reservoirs. Development of the TMDL is not intended to delay any action to improve water quality conditions on the Klamath River in the interim.

26. As explained above, the State Water Board and FERC are required to condition the relicensing of the Klamath Hydroelectric Project to meet water quality objectives and protect beneficial uses. In the interim, Regional Water Board staff is participating in efforts by the Statewide Blue-Green Algae (BGA) Work Group, the Klamath BGA Work Group, and the Drinking Water Program of the DHS to

finalize blue-green algae guidance. The Klamath BGA Group is finalizing sample points for a two year contract awarded to UC Santa Cruz.

27. Regional Water Board staff will continue to work with the counties and Tribes to assure that all efforts are made to effectively inform the public of health concerns as they occur, including:
    - Posting of health alerts by the Regional Water Board if necessary.
    - Continued involvement with the Klamath BGA and the Statewide BGA Work Groups.
    - Work with Drinking Water Program of DHS to finalize statewide blue-green algae guidelines as a voluntary response to BGA blooms.

NOW, THEREFORE, BE IT RESOLVED THAT,

1. Petitioners' request to require PacifiCorp to submit a ROWD for Copco and Iron Gate Dams is DECLINED;

2. Staff shall continue to diligently develop and complete the Klamath TMDLs that will result in compliance with the listed water quality standards;

3. Staff shall work with the PacifiCorp, Tribes, counties, and other interested parties to ensure that all efforts are made to effectively inform the public of health concerns as they emerge this summer, including posting by the Regional Water Board if necessary.

CERTIFICATION

I, Catherine E. Kuhlman, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, North Coast Region, on April 26, 2007.

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Catherine E. Kuhlman

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Addressing Public Health Risks for Cyanobacteria in Recreational Freshwaters: The Oregon and Vermont Framework

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ABSTRACT

Toxigenic cyanobacteria, commonly known as blue green algae, are an emerging public health issue. The toxins produced by cyanobacteria have been detected across the United States in marine, freshwater and estuarine systems and associated with adverse health outcomes. The intent of this paper is to focus on how to address risk in a recreational freshwater scenario when toxigenic cyanobacteria are present. Several challenges exist for monitoring, assessing and posting water bodies and advising the public when toxigenic cyanobacteria are present. These include addressing different recreational activities that are associated with varying levels of risk, the dynamic temporal and spatial aspects of blooms, data gaps in toxicological information and the lack of training and resources for adequate surveillance. Without uniform federal guidance, numerous states have taken public health action for cyanobacteria with different criteria. Vermont and Oregon independently developed a tiered decision-making framework to reduce risk to recreational users when toxigenic cyanobacteria are present. This framework is based on a combination of qualitative and quantitative information.

Keywords: Cyanobacteria Recreational risk Public health Microcystin

Brief Communication

INTRODUCTION

Cyanobacteria, commonly referred to as blue-green algae, are found in many freshwater lakes and rivers across the world. Increasing awareness of the public health risks posed by cyanobacteria has resulted in a burgeoning interest among health officials, lake administrators, the public, and numerous stakeholders who rely on freshwater systems for a variety of purposes. In North America, the most likely exposure pathways to the toxins produced by cyanobacteria in freshwater systems are through recreational contact, contaminated drinking water, or the ingestion of dietary blue-green algae supplements. Exposure to marine cyanotoxins through contaminated fish and shellfish or recreational activities in saltwater are another public health concern. Our intent in this paper is to focus on the public health challenges associated with recreational exposure in freshwater systems to cyanobacteria and to describe the approach adopted by 2 states, Vermont and Oregon.

Human health effects from exposure to cyanobacteria are varied and include gastroenteritis, nausea, vomiting, fever, flu-like symptoms, sore throat, blistered mouth, ear and eye irritation, rashes, abdominal pain, visual disturbances, and potentially severe systemic effects such as hepatic failure, neurological damage, and death (Codd et al. 2005). In addition, cyanobacteria can illicit allergy-like symptoms (Heise 1949), which can include asthma, hives, and conjunctivitis. One of the most commonly reported health effects is skin reaction. A recent study examined acute skin irritant effects in healthy volunteers by skin patch tests with several taxa of potentially toxigenic cyanobacteria (Pilotto et al. 2004). Approximately 20% of the volunteers reacted to the extracts, with mild, self-limiting rashes. Interestingly, no dose–response relationship was established between skin reactions and the density of cyanobacteria.

The 1st recorded scientific observation of cyanotoxin poisoning occurred in 1878, involving cattle, horses, and dogs (Francis 1878). In 1931, the 1st reported human illnesses occurred in West Virginia, when about 9,000 people developed acute gastroenteritis from a cyanobacteria-contaminated drinking water supply (Veldee 1931). In 1959, several people where sickened by a common cyanobacteria, *Anabaena*, as a result of recreational contact in Saskatchewan, Canada (Dillenger and Dehnel 1960). Researchers reported illnesses in 50% of British military recruits who were swimming and canoeing in a lake infested with *Microcystis*, including the development of severe pneumonia in 2 recruits (Turner et al. 1990). In July 2004, Nebraska state environmental and health officials reported an outbreak of symptoms including skin rashes, lesions, blisters, vomiting, and headaches in more than 50 people that were skiing or swimming on Pawnee Lake (Walker 2005). Tests revealed the water was contaminated with microcystin, a common cyanotoxin. A recent summary of illness outbreaks from 1971 to 2000 associated with recreational water in the United States found that algae was implicated in 0.4% of the outbreaks reported (Craun et al. 2005). This number is likely underreported because most reporting to the Centers for Disease Control and US Environmental Protection Agency (USEPA) is voluntary from local and state agencies and blue-green algae is still a novel issue for many local jurisdictions. Furthermore, nearly a quarter of all reported freshwater outbreaks from 1971 to 2000 were of unknown etiology (Craun et al. 2005).

Currently, at least 46 species of cyanobacteria have been shown to produce toxins harmful to vertebrates (Chorus and Bartrum 1999). Some of the more common toxigenic genera include *Microcystis*, *Anabaena*, *Aphanizomenon*, *Lyngbya*, *Nodularia*, *Planktothrix*, *Nostoc*, and *Cylindrospermopsis*. The

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EXHIBIT A

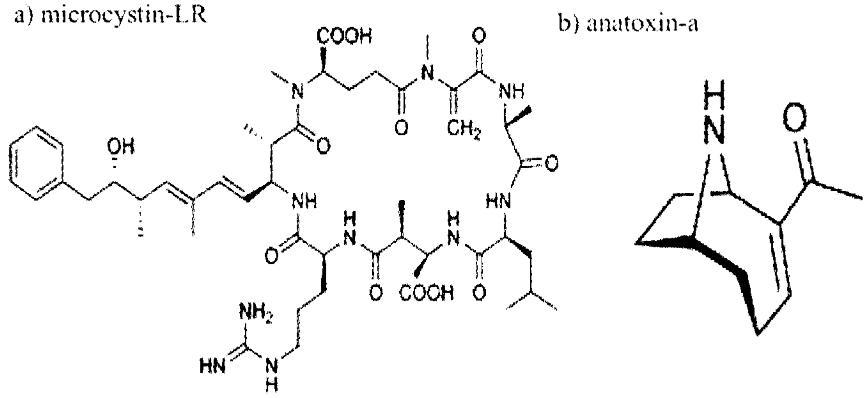

Figure 1. Molecular structure of (a) microcystin-LR and (b) anatoxin-a.

cyanotoxins that have been detected in freshwaters of Oregon include microcystin, anatoxin-a, and cylindrospermopsin, and microcystin has been detected in Vermont. It should be noted that cyanobacteria likely produce toxins that have not been characterized or are not commonly sampled. A recent example is the discovery of a neurotoxic amino acid, β-*N*-methylamino-L-alanine, which was detected in the vast majority of cyanobacteria tested (Cox et al. 2005) and might be associated with some neurodegenerative diseases (Murch et al. 2004; Ince and Codd, 2005). Microcystins are the most commonly detected freshwater cyanotoxins across the world (Chorus and Bartrum 1999). This toxin is produced by numerous taxa and has more than 95 known structural variants, including the most researched variant, microcystin-LR (Figure 1). Microcystin primarily targets liver cells. The mechanism of toxicity is the inhibition of protein phosphatases, resulting in high phosphorylation of cytoskeletal filaments, which can lead to internal hemorrhaging of the liver. Damage to the liver from subacute exposure is likely to go unnoticed up to levels near those that cause severe damage following acute exposure (Chorus et al. 2000), indicating a steep dose–response curve. From a chronic exposure perspective, microcystins are considered to be tumor promoters on the basis of studies in mice that were initiated with a known carcinogen (Falconer and Buckley 1989).

A neurological cyanotoxin of public health significance is anatoxin-a (Figure 1), which is produced by several cyanobacteria. Anatoxin-a is a cholinergic agonist that binds to neuronal nicotinic acetylcholine receptors. The molecular activity of anatoxin-a leads to overstimulation of muscle cells and possibly paralysis followed by asphyxiation (Carmichael 1997). In Oregon and Vermont, multiple dog deaths are suspected to be the result of exposure to anatoxin-a, which was detected in the water at the time of death in some incidents.

CHALLENGES

Many aspects of cyanobacterial behavior pose challenges to the protection of public health. The temporal and spatial variability in cyanobacterial growth are particularly difficult for monitoring recreational waters, especially when budgetary and staffing resources are limited. As an example, cyanobacteria can reach scum-forming densities or they can die off in 1 or 2 d. If monitoring is conducted weekly, these rapid blooms can be missed in a surveillance program. Many lakes are large and highly dendritic, with a large degree of spatial heterogeneity in cyanobacteria density. Often, the cove, arms, or slackwater areas are more conducive for scum formation, which might be missed in a sampling program. Some lakes could be more susceptible to bloom formation as a result of natural or anthropogenic eutrophication or through alteration of food web dynamics from the introduction of exotic species. Other waterbodies can be highly influenced by climatic factors that influence the potential for blooms.

Some species of cyanobacteria prefer to grow at lower depths in the water column or have the ability to regulate their buoyancy, which present further challenges if the determination to issue a health advisory is based on the presence of visible scum or sampling only occurs near the surface. To address some of these considerations, we have suggested that surveillance programs focus on designated recreational areas if resources are limited, such as swimming locations, campgrounds, boat ramps, and other known sites that attract children and families (ODHS 2005). We also advocate for increasing the awareness and education among field staff and the public to assist in visually identifying and reporting blooms to enhance surveillance capabilities.

The factors that determine whether a bloom will produce toxins are poorly understood. Toxin production has been described as highly variable, both within and between blooms (Codd and Bell 1985). Significant differences in toxicity can occur within distances of only meters within the same bloom (Carmichael and Gorham 1981). The biotic and abiotic factors that influence toxin production have been examined in some taxa. Temperature and solar radiation have been suggested to play a role on toxin production in *Microcystis aeruginosa* (Van der Westhuizen et al. 1986; Codd and Poon 1988). Beyond the lack of understanding for toxin production, many data gaps exist in the toxicological studies of cyanotoxins. For microcystins, a provisional tolerable daily intake was developed by the World Health Organization on the basis of the LR variant only (Fawell et al. 1994). Numerous other variants of microcystins have known or unknown levels of toxicity that remain poorly characterized. At this time, no reference dose is available for anatoxin-a. Further toxicity studies are needed to determine the effect of

Table 1. Generalized list of primary exposure pathways of concern for cyanotoxins during recreational activities

Exposure potential	Recreational activity	Primary exposure pathways of concern
High	Swimming/wading	Ingestion
	Diving	Ingestion
	Water skiing/wake boarding	Ingestion/inhalation
	Wind surfing	Ingestion/inhalation
	Jet skiing	Ingestion/inhalation
Moderate	Fish/shellfish consumption	Ingestion
	Canoeing	Inhalation/dermal
	Rowing	Inhalation/dermal
	Sailing	Inhalation/dermal
	Kayaking	Inhalation/dermal
	Motor boating (cruising)	Inhalation
Low/none	Catch and release fishing	Dermal
	Hiking	Not applicable
	Picnicking	Not applicable
	Sightseeing	Not applicable

repeated exposures to environmental concentrations of cyanotoxins over a time span that ranges from a few days to several months. Even less information is available from rigorous epidemiological studies.

No single disease or symptom complex in humans can completely characterize exposure to cyanotoxins, making diagnosis difficult without surveillance of water systems. Many of the symptoms that can be caused by cyanotoxins overlap with those caused by other agents found in environmental waters, such as cercarial dermatitis and other protozoan, bacterial, or viral agents found in water. A specific diagnostic test for humans is not readily available. Water sampling for toxins after a suspected poisoning or illness is often delayed and might not accurately reflect the current conditions when exposure occurred. Furthermore, symptom or disease reporting from local health departments or physicians is expected to be low because cyanobacteria-related illnesses are still an emerging public health issue. Outreach activities to county health departments, especially those counties with historical cyanobacterial blooms, continue in Oregon and Vermont. Statewide websites have been established to track current and past advisories in Oregon and Vermont (www.oregon.gov/DHS/ph/envtox/maadvisories.shtml and http://healthvermont.gov/enviro/bg_algae/bgalgae.aspx, respectively).

EXPOSURE ASSESSMENT

In recreational waters, the exposure to cyanotoxins can occur through oral ingestion, aspiration of water into the lungs, inhalation of mist, and dermal contact. Different recreational activities are associated with differing risk levels when toxigenic blooms are present (Table 1). It should be noted that Table 1 is a general outline and the primary exposure pathway of concern depends on the details of the activity. For instance, if a canoe capsizes, the primary concern could change from dermal exposure to incidental ingestion or aspiration of water.

Ingestion of water can occur through both incidental and intentional pathways. Incidental ingestion is more likely to occur in recreational waters compared with intentional ingestion, especially in turbid or discolored waters. The risk of incidental ingestion is particularly high for children playing in nearshore areas where scums tend to accumulate. A possible scenario for the intentional ingestion of recreational water is the use of lake or river water for drinking or cooking purposes, especially by campers and hikers. It is likely that some people believe that boiling, filtering, or treating contaminated water with conventional outdoor equipment will eliminate the risk posed by toxins, which in many cases are ineffective against cyanotoxins. In addition, it is important to identify recreational waters that might serve as drinking water sources. This includes water users at the affected waterbody, such as private homes, campgrounds, lodges, and ranger stations and those with intakes downstream.

Inhalation or aspiration of toxin is more likely through activities in which the toxin is aerosolized in water droplets, such as wake boarding, water skiing, or diving activities. The toxicity of cyanotoxins tends to be higher when the toxin enters through the respiratory tract, compared with the oral ingestion pathway (Chorus et al. 2000).

A frequent question in Oregon and Vermont is the health risk posed by consuming fish caught during a bloom. Studies have shown that microcystin mainly accumulates in the liver and viscera of fish, although it has been detected in the fillet (Vasconcelos 1999; de Magalhães 2001; Mohamed et al. 2003). In addition, shellfish have been shown to accumulate cyanotoxins in edible tissue (Vasconcelos 1999; Sipia et al. 2001). A recent study examined the bioaccumulation of microcystin in several trophic levels of freshwater fish (Xie et al. 2005). Levels of microcystin-LR and -RR were measured in various organs and compartments of fish during a dense

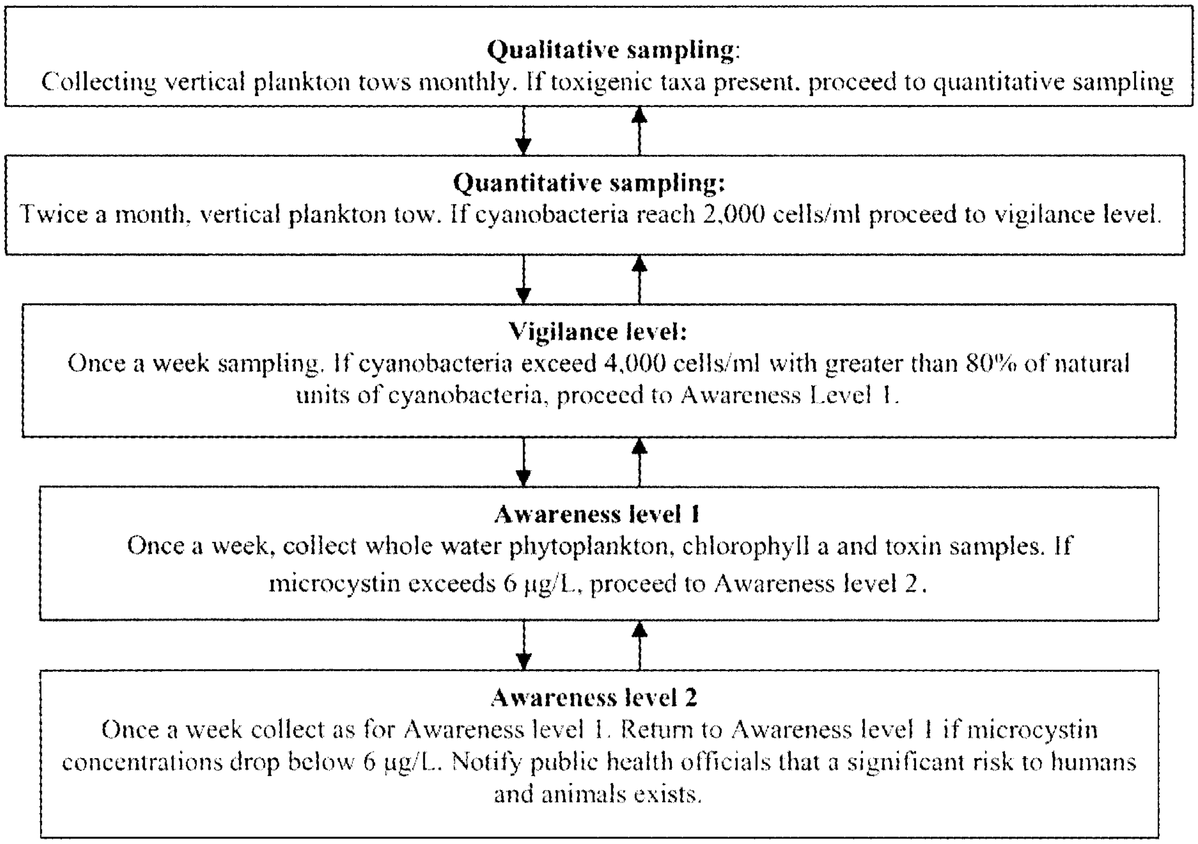

Figure 2. Tiered surveillance and notification system used by Vermont for cyanobacteria.

bloom of *Microcystis* and *Anabaena*. Although most of the microcystin content was detected in the blood, bile, gut contents, and liver, the muscle content averaged 1.8 μg microcystin/g tissue dry weight, with the highest accumulation in fish occupying the upper trophic levels. From their conclusions, 100 g (~4 oz) of fillet can contain up to 25 times the tolerable daily intake for microcystin.

In Oregon, anglers are encouraged to thoroughly clean the fillet and discard gut contents and organs before cooking. During particularly dense blooms of toxigenic species or high toxin production, anglers have been advised to avoid consuming fish from those waters. It should be noted that microcystins are heat stable and not broken down by the heat generated through cooking (Harada et al. 1996).

VERMONT APPROACH

Cyanobacteria 1st made news in Vermont when 2 dogs died in Lake Champlain after playing in a bloom. The cause of death was determined to be from cyanobacterial toxins. Since then, the Vermont Department of Health and the University of Vermont have collaborated in monitoring the lake for cyanobacteria and 2 toxins, microcystin and anatoxin-a. Lake Champlain is the major lake in Vermont and shares lakefront with Canada and New York state. One particular part of the lake, Missisquoi Bay, which is the tributary of the Missisquoi River, has been heavily contaminated with microcystin-producing cyanobacteria (Watzin et al. 2003). Peak concentrations occur annually in August.

A tiered system was established for surveillance of cyanobacteria in Lake Champlain (Figure 2). The surveillance begins with qualitative sampling that progresses in frequency of monitoring as blooms develop. Lake Champlain has 14 monitoring locations and the University of Vermont and volunteers collect samples. The Vermont Department of Environmental Conservation assists with monitoring for the presence of blooms and sample collection by boat. The guideline for beach closings is the visible presence of cyanobacterial scum. Beach reopening can occur if no visible scum is present and the concentration of microcystin-LR is 6 μg/L or less. The 6 μg/L guidance value was based on a recreational childhood swimming scenario outlined below.

$$\text{Guidance value}(\mu g/L) = \frac{\text{TDI} \times \text{BW}}{\text{IR}}$$

The tolerable daily intake was developed by the World Health Organization on the basis of repeated oral administration of microcystin-LR in mice and effects on the liver. The tolerable daily intake of microcystin-LR is 0.04 $\mu g \cdot (\text{kg body weight})^{-1} \cdot d^{-1}$. A body weight of 15 kg was used to represent a child. An ingestion rate was based on USEPA guidance for incidental ingestion of surface waters, in which 0.05 L/h is accidentally ingested (USEPA 1991; Dang 1996). For this guidance, it was assumed that a child would swim for up to 2 h in a single day.

Vermont has 2 types of postings for beaches. One is an informational poster to raise public awareness of cyanobac-

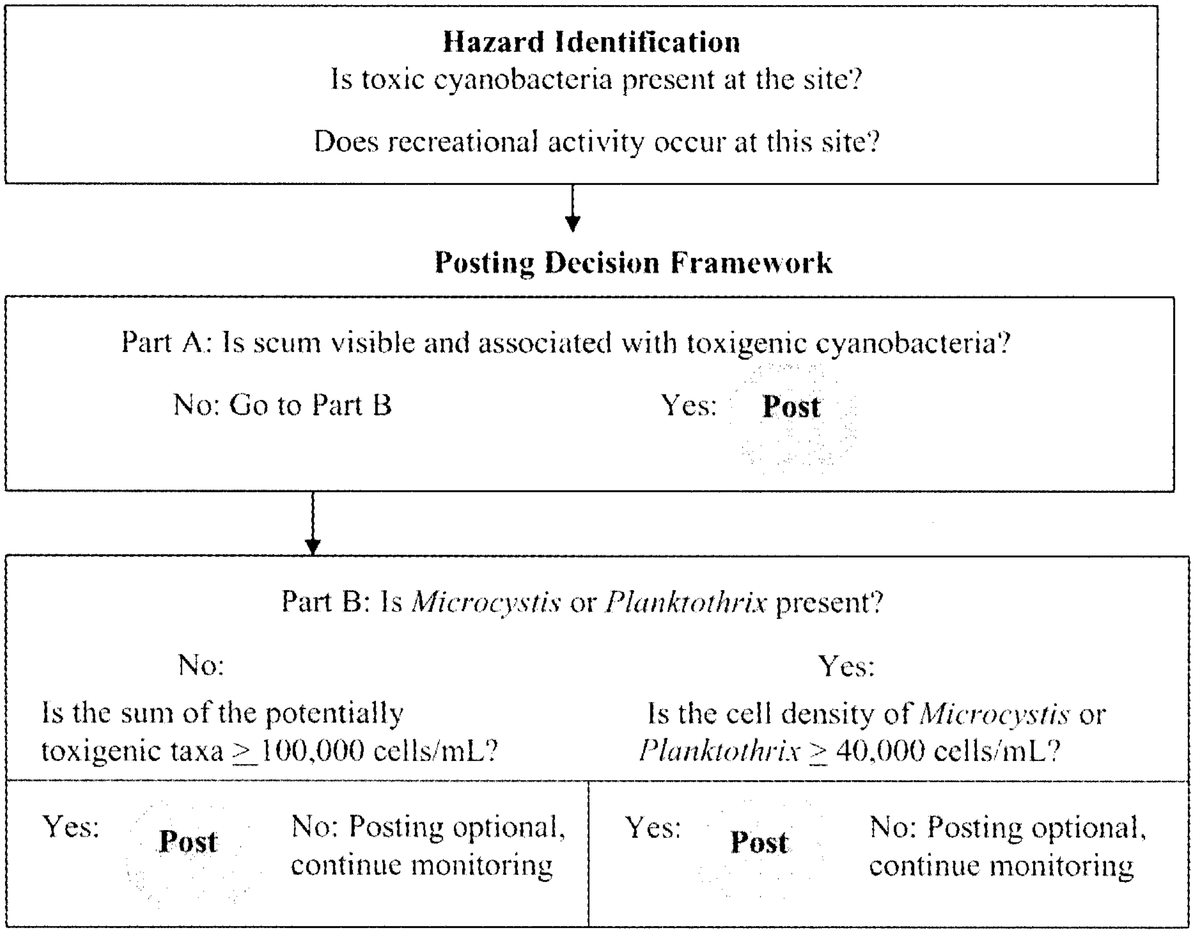

Figure 3. Decision framework for issuing advisories in recreational waters in Oregon for cyanobacteria.

teria and scum formations and the other is a "Beach Closed" sign for public swimming beaches. Private property is not posted. A website with a map is updated weekly to reflect results and locations of the testing program. The website uses a color-coded schematic to identify generally safe, low-alert, and high-alert areas. The website also hosts fact sheets and press releases for public education.

The Vermont Department of Health has been training local town Health Officers to identify cyanobacteria and to take water samples in lakes and ponds with public beaches. These samples are analyzed for microcystin toxin. Sampling kits for microcystin are available to Health Officers and state environmental personnel to test the water for toxin. The state does not have the capacity to provide test kits for anatoxin but hopes to develop this ability in the near future.

OREGON APPROACH

Currently, several waterbodies in Oregon are monitored for toxigenic cyanobacteria. These include publicly owned recreational waters, privately owned lakes, and some drinking water systems. A variety of stakeholders administer the lakes, including federal, tribal, state, county, and city governments; utility companies; and private corporations or landowners. In past years, the decision-making process for issuing and lifting advisories varied with the managing jurisdiction of that waterbody. In 2004, an interagency cyanobacteria taskforce was created with representation from government agencies, academia, and the private sector. One intention of the taskforce was to adopt statewide public health guidelines for issuing and lifting advisories in recreational waters when toxigenic cyanobacteria are detected.

In 2004 and previous years, Oregon lakes were posted when toxigenic cell densities exceeded 20,000 cells/mL, corresponding to an Alert Level III according to World Health Organization recommendations. In 2005, the interagency blue-green algae task force recommended 2 mechanisms to issue an advisory in Oregon for recreational waters (Figure 3). The 1st mechanism is the identification of visible scum dominated by potentially toxigenic cyanobacteria. This observation, which is often determined by trained field staff, will result in the immediate posting of the affected waterbody. Scum formation could increase toxin production by orders of magnitude in a few hours (Chorus and Bartrum 1999). The 2nd mechanism uses cell density to trigger an advisory. The task force recommended that advisories be posted if the cell density of total toxigenic cyanobacteria equals or exceeds 100,000 cells/mL, unless the bloom has *Microcystis* or *Planktothrix* species. The World Health Organization guidance for a moderate health alert is

100,000 cells/mL (Chorus and Bartrum 1999) on the basis of a risk management decision by the interagency task force.

A lower guideline of 40,000 cells/mL was recommended for advisories for blooms that contain *Microcystis* and *Planktothrix*. The lower guideline is based on the premise that these 2 genera are more likely to produce microcystin toxin compared with other genera, such as *Anabaena* (Codd et al. 2005), and the observation that almost all *Microcystis* strains are toxigenic (Carmicheal 1995). The lower *Microcystis* and *Planktothrix* guideline is estimated to correlate with the production of 8 μg/L of microcystin (Chorus and Bartram 1999), which is the guidance value used by Oregon. Posting of a waterbody is accompanied by a press release to various media outlets.

In addition to recommendations for the posting of advisories, the task force outlined guidance for retracting advisories. Cyanotoxins, if produced, are typically found within the cell during most of a bloom event. As the bloom senesces, toxin can be released into the dissolved phase of the water when the cells die and lyse. The released toxin will dilute and eventually degrade over time. However, the risk of exposure to dissolved toxin immediately after the peak of a bloom must be addressed because cyanotoxins can persist even though the bloom has dissipated (Lawton et al. 1994). An additional risk factor is that the water will appear more inviting for recreational activities as the clarity increases, thus elevating the potential for exposure during this period.

The task force recommended that an advisory be lifted after a waiting period of 2 weeks once the cell density of potentially toxigenic blue-green algae falls below recommended guidelines and with sufficient evidence that the bloom is continuing to decline. Evidence of a declining bloom can include decreasing cell density of potentially toxigenic cyanobacteria and increasing lake clarity measured with a Secchi disk or particle counter. If toxin analysis is conducted, an advisory may be lifted 1 week after the cell density falls below recommended guidelines, if microcystin is below 8 μg/L. The guidance value of 8 μg/L was derived in a similar manner to the process used by Vermont, with the difference that 20 kg was used as the default child body weight in Oregon. It should be noted that these advisories are not lake closures. Rather, they are intended to provide the public with information that indicates a public health hazard might exist. Under extreme conditions, or if evidence exists of illness, the appropriate jurisdiction for a waterbody can invoke an official closure.

An essential part of the educational and outreach efforts for cyanobacteria is the posting and distribution of informational signs and pamphlets. Ideal places to post include kiosks, docks, bulletin boards, trailheads, campgrounds, and other visible locations that advise on the effects and symptoms that are possible with exposure to cyanobacteria. Posted information should include a notice that not all waters can be monitored all the time and scummy, turbid, or discolored waters should always be avoided. A further notice should warn that children, individuals with pre-existing medical conditions, and the elderly are considered susceptible populations. Oregon State Public Health maintains a Web-based listing of current and past advisories across the state.

NATIONAL RESPONSE

In December 2004, the Harmful Algal Blooms and Hypoxia Research and Control Act (HABHRCA) was reauthorized and expanded to include freshwater and cyanobacteria. This act forms the basis for the reestablishment of a federal interagency task force. As part of the proposed scientific assessment of freshwater harmful algal blooms, the frequency and occurrence of significant blooms will be assessed from an ecological and economic perspective. In addition, HABHRCA established priorities and guidelines for an interagency research program to gain a better understanding of the causes, characteristics, and effects of harmful algal blooms in freshwater locations. Finally, HABHRCA will identify ways to improve coordination and reduce duplication of efforts among federal agencies and departments.

In addition to the expanded role of HABHRCA, there have been some promising recent developments at the federal level by various agencies. The National Toxicology Program has nominated 2 cyanotoxins for toxicity testing. The Centers for Disease Control has provided some financial and technical assistance to a limited number of states and plans to conduct a health outcome study in a recreational setting. In 1998, the USEPA included cyanobacteria and their toxins on the Contaminant Candidate List, which is a list of known or potential drinking water contaminants for regulatory consideration. Currently, the United States has no drinking water or recreational guidelines or regulations for cyanotoxins, prompting states to use information and guidance from the World Health Organization or other countries. Recently, the USEPA sponsored an international symposium on cyanobacteria and harmful algal blooms in September 2005, in part to meet the mandates of the HABHRCA (ISOC-HAB 2006). Other agencies, such as the US Geological Survey, the Army Corps of Engineers, and the US Fish and Wildlife, have been active in monitoring and management issues with cyanobacteria as well.

Although the recent attention at the federal level and the goals of the HABHRCA are laudable, we advocate for stronger research and funding on public health issues, including relevant toxicological and epidemiological studies. The extent for cyanotoxins to contaminate fish and other food items, the lack of reference or tolerable doses for many cyanotoxins, improved monitoring techniques for recreational waters, and research directed toward determination of toxigenic strains and toxin production are needed. These should be accompanied by outreach efforts toward county health departments, veterinarians, and local physicians in areas that have high water recreation activities and a history of toxigenic blooms. We hope that more effort will be directed toward addressing these public health concerns and providing national guidance for cyanobacteria in recreational scenarios. Until this occurs, various states, counties, and other entities will continue to apply diverse criteria to address cyanobacteria or ignore the problem altogether.

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